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ABSTRACT

This document contains 45 integrated physics, mathematics, and technology curriculum modules developed by teachers at 5 Illinois schools. An introduction discusses the collaborative project, in which teams of one mathematics, physics, and technology teacher from each school developed innovative instructional delivery models that enabled the three teachers to teach the integrated content together and develop curriculum modules (activities). The five integrated instructional models are described, and evaluation findings are reported. Activities are presented by high school. Components of each activity are as follows: technological framework; purpose; Illinois learner outcomes; concepts; prerequisites; materials, equipment, apparatus; time frame; teaching strategies; teaching methodology; further fields of investigation; procedure; anticipated problems; evaluation; follow-up activities; references, resources, vendors; and figures, postlab questions, and mathematics worksheets. Topics include the following: laser burglar alarm; capacitance; relative humidity sensors; variable resistor; industrial safety; fiber optics; development of a solar-powered transporter; Hall Effect; reflection holography; photosensitive devices; curved mirrors; sensors in an automated industrial system; separation systems aspirator/screens; metered mixture with augers; grain moisture tester; nozzles and spraying; plow/force; soil compaction; belt sander; variable resistance; exercise machines; generator; laser survey; power tools; ultrasound; computer operated lathe; automated assembly line with scrobot; addition of velocity vectors; measuring buoyancy with force transducer; torque wrench lab; computer interfaced thermocouple; fiber optics multiplexing system; inertia welder; electromagnetic door control; smoke alarm; programmable home thermostat; xerography; bar coding; cryogenetics; centrifuge; commercial ice machines; and AM/FM signals. (YLB)

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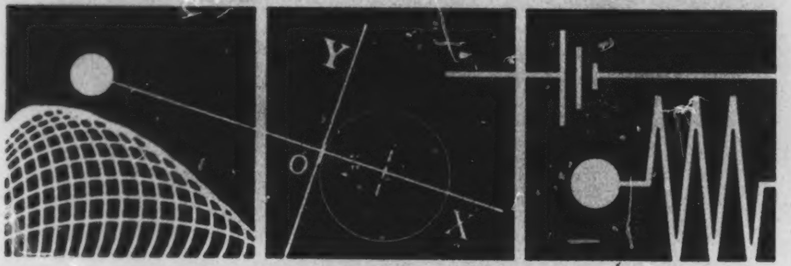

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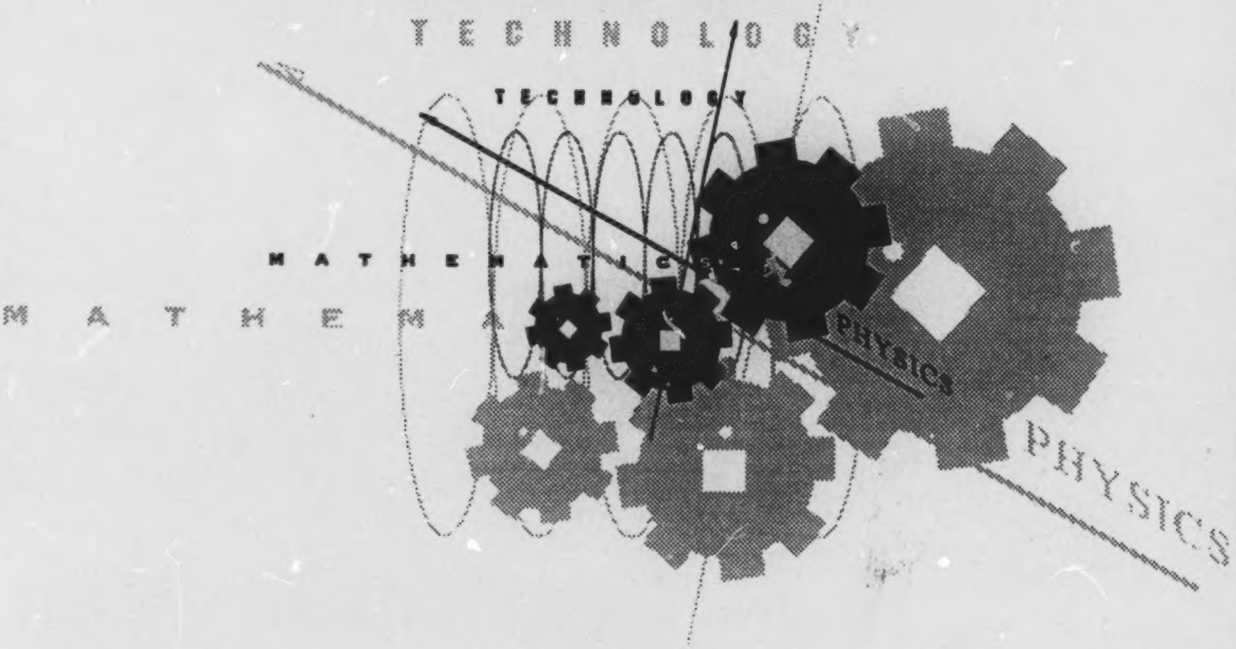

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AN INTEGRATED PARTNERSHIP

PHYS-MA-TECH

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TABLE OF CONTENTS

Inclusive Page Nos.

INTRODUCTION . . . . v-xvii

Grayslake High School

List of Activities 1
Activity 1: Laser Burglar Alarm 2-13
Activity 2: Capacitance (RC Time Constant) 14-26
Activity 3: Relative Humidity Sensors (Hygropak Type) 27-41
Activity 4: Variable Resistor (Gas Sensor) 42-52
Activity 5: Industrial Safety (Loudness Sensor and Noise) 53-62
Activity 6: Fiber Optics 63-76
Activity 7: Development of a Solar-Powered Transporter 77-88
Activity 8: Hall Effect 89-102
Activity 9: Reflection Holography: Stress Test of Materials 103-117
Activity 10: Photosensitive Devices . . . 118-129
Activity 11: Curved Mirrors 130-156
Activity 12: Sensors in an Automated Industrial System 157-199

Moline High School

List of Activities 200
Activity 1: Separation Systems Aspirator/Screens 201-210
Activity 2: Metered Mixture with Augers . 211-222
Activity 3: Grain Moisture Tester 223-233
Activity 4: Nozzles and Spraying 234-242
Activity 5: Plow/Force 243-255
Activity 6: Soil Compaction 256-262
Activity 7: Belt Sander 263-278
Activity 8: Variable Resistance (Dimmer Switch) 279-301
Activity 9: Exercise Machines 302-314
Activity 10: Generator 315-329
Activity 11: Laser Survey 330-339

Inclusive
Page Nos.

Moline High School (continued)

Activity 12: Power Tools 340-354
Activity 13: Ultrasound 355-364

Shepard High School

List of Activities 365
Activity 1: Computer Operated Lathe (CAD-CAM), Parts 1 & 2 366-373
Activity 2: Computer Operated Lathe (CAD-CAM), Part 3 374-383
Activity 3: Automated Assembly Line with Scorbot 384-392
Activity 4: Teaching Physics Concepts Using the Scorbot ER-III 393-416
Activity 5: Addition of Velocity Vectors 417-432
Activity 6: Measuring Buoyancy with a Force Transducer 433-446
Activity 7: Torque Wrench Lab 447-456
Activity 8: Computer Interfaced Thermocouple 457-466

Aurora West High School

List of Activities 467
Activity 1: Fiber Optics Multiplexing System 468-490
Activity 2: Jack of All Trades 491-523
Activity 3: Inertia Welder (Friction Welding) 524-534
Activity 4: Electromagnetic Door Control . 535-553
Activity 5: Smoke Alarm 554-566
Activity 6: Programmable Home Thermostat . 567-577

Curie High School

List of Activities 578
Activity 1: Xerography 579-591
Activity 2: Bar Hopping: Bar Coding . . . 592-621
Activity 3: Cryogenetics 622-636
Activity 4: Centrifuge 637-651
Activity 5: Cold Cuts: Commercial Ice Machines 652-673
Activity 6: AM/FM Signals 674-706

INTRODUCTION

Background

In January of 1990, teachers from five schools in Illinois began working with Professor Jule Scarborough at Northern Illinois University (NIU) on a collaborative project funded by the National Science Foundation, the Illinois State Board of Education, Department of Adult, Vocational and Technical Education, and NIU's College of Engineering & Engineering Technology.

The overall project goal was to improve high school physics, without diminishing the content or rigor of the physics, for the purpose of encouraging those students who do not traditionally enroll in physics to do so. Comparatively few high school students actively select physics as a science option while in high school. There is a very large number of students in each high school categorized as "average" in their performance who have the ability to do well in physics, but who resist or choose not to enroll for a variety of reasons. The same is often true for upper-level mathematics and technology courses.

The path chosen to achieve the project goal began with acknowledging the inherent relationship of physics, mathematics, and technology. Therefore, the focus of the educational reform was to restructure the content and instructional delivery of physics, mathematics, and technology, integrating the academic content and instructional delivery of the three disciplines to improve physics.

To restructure the academic context, administrators, school staff, and teams of one mathematics, physics, and technology teacher from each school developed innovative instructional delivery models which provided opportunity for three teachers to teach the integrated content together. The teacher teams analyzed course contents for commonalities in concepts and skills across the three disciplines which resulted in the development of integrated physics, mathematics, and technology curriculum modules.

The integrated instructional delivery models and curriculum modules were field tested, and research and evaluative information was collected during the 1990-91 school year. During the summer of 1991, the delivery models and curriculum modules were modified or revised based upon evaluation.

It was important to the project director, teams, and funding agencies that the models and materials developed as part of this endeavor be transferrable to other schools. Therefore, there was an effort to involve a wide variety of characteristics in pilot schools, teachers, administrators, and students. There was a vast variety of economic levels, talent, personalities, skills, knowledge, abilities, resources, etc. across the project pilot sites.

The most important outcome of the project was "how" the teachers worked together, taught together, used each other's knowledge and skills, learned from each other, and generally worked together using the integrated instructional delivery models. Even more important was how the perception of the students changed regarding the teachers, the courses, and their experience when "seeing" the teachers work together and experiencing them teaching together. Of course, the integrated modules were important, but they were simply the vehicles which organized the knowledge, skill, and learning experience. They will, however, serve as a catalyst for other teachers to group around and begin an integrated initiative of their own and/or as additional integrated curriculum materials for those who have already begun.

Integrated Instructional Delivery Models

During the first pilot year, each of the schools assigned three teachers (one each of physics, mathematics, and technology) to teach an integrated course encompassing the three disciplines. Because we chose physics as the focus for our reform, we integrated using the existing physics courses as the central "course" in the system for credit in all but two schools. However, it could easily have been electronics, mathematics, or any other "course." Or, as in one of the pilot schools, several types of courses and credit could be offered using several time blocks. One school also used the traditional rotation model with innovative modifications. All but that school initially piloted the models assigning more than one teacher to a single group of students, which was very expensive. Described below are the integrated instructional delivery models used when teaching integrated physics, mathematics, and technology at the project schools. Noted as well for each model are the modifications of each model for use during the 1991-92 school year to reduce the expense of multiple teacher assignments to one student group without reducing the level of integrated teaching.

* It is important to note that these schools not only chose a
* philosophy of integrating both content and delivery, but deter-
* mined that there was no need to create a new course(s). Appro-
* priate and quality course content existed; the philosophy and
focus was to teach it differently and better so that students
not traditionally enrolling would realize the potential of such
courses for themselves and be motivated to enroll.

Model A

Three teachers (one each physics, mathematics, and technology) were assigned to one class of students (24) for one credit in physics, one-half credit in mathematics, and one-half credit in technology for a two-hour (or two-period) time block. This delivery model was "one teacher" more expensive than traditional delivery because of the two-hour time block and three types of credit. This model was modified such that the "third" teacher was assigned a non-academic duty (e.g., study hall) during the same time period as the integrated class, allowing him/her to swing or float in and out when needed. This did not reduce the level of integration in content, delivery, or interaction.

This integration experience was taught in a newly developed science and technology laboratory, also making use of several other technology laboratories.

Model B

Three teachers (one each physics, mathematics, and technology) were assigned to one class of students (24) for one credit in physics for a 50-minute time block. This model was "two teachers" more expensive than traditional delivery. This model was taught in the same way during the 1991-92 year, but will be modified, using "swing" position(s) as well.

This integration experience was taught using both traditional physics and technology laboratory facilities.

Model C

Two teachers were assigned to one class of students (24) during the same time period. A third teacher was assigned to an academic supervision during that same time period for one credit in physics for a 50-minute time block. This model was one teacher more expensive than traditional expenditure. The third teacher "exchanged" places with one of the other teachers when needed. This did not reduce the level of integration or interaction among team members. This model will continue with two teachers assigned to one class and one "swing."

This model was taught the same way during the 1991-92 school year. The integration experience was taught using both the traditional physics and technology laboratories.

Model D

Two teachers were assigned to one class of students (18); a third teacher was department chair and used his administrative planning period as time to "swing" or "float" into the class when needed. The class was taught for 50 minutes daily for one credit in physics. Once again, the "swing" position did not reduce the level of integration or teacher interaction. The administrative faculty member spent the majority of his time in the class.

The model continued during the 1991-92 year, and will continue with two teachers assigned to one class. It was taught in both the traditional physics and technology laboratories.

Model E

One group of students (24) was enrolled in each of three courses--electronics, physics, and a combined upper-level mathematics. Therefore, three teachers, three courses, three credits (one for each course), one classroom, and two laboratories were utilized. Note that these courses were not scheduled back to back. The teachers integrated course content using the integrated modules teaching the same information from the perspective of each respective discipline so that there was transferral and reinforcement of information from one classroom or laboratory to the other on the same days. They had permission as well to "switch" positions with each other during each other's classes when appropriate to reinforce transferability of information or to use each other's expertise. This worked because the courses were coordinated so well that it was not disruptive to have the teachers switch positions for small "sub" blocks of time within one time period. This model was very effective, and the students liked it when the teachers "switched" and referred to each other's content and classes. The students fell into the routine of walking into each class, telling and/or asking the teacher what was to be covered based upon what had occurred in the previous class, etc. However, this model is more difficult to maintain because of less teacher contact time and requires very dedicated teachers to be as successful as it was during our piloting and/or to be sustained long term. This model required standard traditional expenditure and no extra expense was necessary.

Scheduling several classes back to back, beyond the two-hour block of time used in Model A, such that one or more groups of students are enrolled in several different classes to be integrated was also considered a viable model with untapped potential. The blocking would allow for greater flexibility in student grouping, teacher roles, content, group experiences, field trips, etc.

In the final analysis, the schools have committed to sustaining integration in both academic content and instructional delivery (teaching) long term. Most of the models have been modified to use the non-academic "swing" or "float" duty positions scheduled simultaneously to reduce the expense. However, they have not reduced integration or teacher interaction. Several schools are continuing to assign more than one teacher to a single class. Each school plans to continue scheduling simultaneous preparation periods for the teacher teams so that they have planning access to each other. This is critical to the success of integration endeavors. Teachers must have time to plan and prepare together. In addition, there have been spin-offs. Other teachers and teams across disciplines have begun integration activities in these schools as well. In most of these schools, this project was the initial impetus for integration.

Final Notes Important to Integration Initiatives

Non-traditional scheduling is the answer to integrated teaching and instructional delivery. It is difficult to develop and maintain an integrated curriculum without commitment to integrated delivery. These schools committed themselves to the philosophy of integrated content and delivery, and found that once the barrier of "traditional" mind set towards master scheduling had been overcome, there were feasible creative options that provided an opportunity for teachers to teach together long term. Critical to integration initiatives are the following:

- Provide simultaneous preparation periods for teachers working together.

- Do not develop a new course/new title without in-depth consideration; in most cases, good content and courses already exist. There is a need to teach differently using integration as a method and philosophy.

- Begin at a rate that ensures gradual success.

- Provide inservice for other teachers as your first or second initiatives progress.

- Keep your board of education and community informed and involved.

- Keep in mind that communication between integration team members and between the team(s) and other teachers, administrators, etc. is crucial to success.

- If incompatibility exists among initial team members, do not hesitate to consider changing team members.

Spin-Offs

One school is planning to integrate different mathematics, science, and technology courses for each of the four high school years. This will provide students the opportunity to choose an integrated mathematics, science, and technology curriculum.

Another school is developing a second course in engineering that will further establish the relationship between science, mathematics, and technology. This course will be an advanced course to be taken after the initial physics, mathematics, and technology course. The teachers and administrators in this school are also providing inservice for all science, mathematics, and technology teachers in the district so that integration can occur district-wide.

Several schools have integrated more classes now that the piloting and project are completed. And, one district is reorganizing so that mathematics, science, and technology share the same administrative unit.

Evaluation

Several types of evaluation occurred throughout the project. Internal to the experimental research design was evaluation of the instructional delivery models and integrated curriculum modules as well as the teacher interaction while teaching. In addition, both teachers and students evaluated the integrated modules. Also, parents, students, administrators, and teachers evaluated the experimental (integrated) approach to content and instructional delivery of physics, mathematics, and technology education. Finally, an external evaluator evaluated the project in nature, merit, operation, and outcomes. The following resulted from evaluation:

Research

The research findings provide evidence suggesting that integrating physics, mathematics, and technology in content and instructional delivery (teaching) is a very appropriate method for teaching rigorous high school physics (mathematics and technology), without reducing the rigor, to students that are less academically (GPA) talented than traditional physics students. The students enrolled for the experimental (integrated) approach were a cross-section of students falling within the "average" performance range, those students who for a variety of reasons tend not to take high school physics. The measures (tests) used for both the experimental (integrated) and control (traditional physics) classes were exactly the same. Both groups learned the same physics at the same rate just as well, using the same test to measure achievement. Considering that the experimental students were less academically talented and that the teachers were piloting (field testing) new curricula and new teaching methodologies (team teaching), were also learning new technologies (hardware, software) in addition to each other's content, and were under extreme time constraints, etc., this was a remarkable outcome. Beyond the measure for knowledge gain, a science attitude measure was used. We found that the experimental (integrated) students enrolled for a variety of reasons, but that the traditional (control) students enrolled because it seemed to be a requirement for college entrance. At the end of the year, there was a major shift in attitude regarding the reason for being enrolled in physics; more of the experimental (integrated) and significantly fewer of the control (traditional) students expressed their reason for being in physics as that of it being necessary for them to go on to college. This indicates that success in physics may make a difference in attitude and expectations. Also, misperception on the part of a student can limit his/her access to particular courses. If students "perceive" that they cannot succeed or do well in physics, that there are special (unwritten) prerequisites, or that they are not appropriate as a student to be in the course, even though this may not be true, they will not enroll in such a course.

Physics, Mathematics, and Technology Teacher Project Evaluation

Upon finishing the field test year, project teachers generally felt very positive about using and continuing to use both the integrated curriculum modules and integrated instructional delivery models. In every school or district, there were positive "spin-offs" as a result of this integrated effort. The teachers collectively found that common (simultaneous) planning or prep periods were essential for teachers integrating content and delivery. Time to develop and continue to develop integrated activities was found to be essential as well. And, finally, long-term administrative support was viewed as mandatory for integration to work long term. Some of the issues that will continue are those of common planning time, sustaining the integrated instructional delivery together as a team through creative non-traditional scheduling (using the swing non-academic positions), teacher learning time, etc. All except one of the teachers indicated that they would involve themselves in other major educational reform endeavors such as this again. Collectively as teachers, they felt that they had gained an unbelievable appreciation for each other and a sense of togetherness, respect, and awe for the knowledge and experience individually and collectively available once they got to know each other better. They felt that the opportunity to work together increased their professional potential, their access to resources, their awareness of what is going on and/or covered across disciplines, their chance to be on the cutting edge with technology, methodology, trends, and their opportunity to be leaders. Most of the teachers felt that the internal/external support groups made up of school personnel, business and industry individuals, school board members, etc. will be beneficial to sustain integration long term. Generally, the teachers felt that integration in content and delivery will continue in their schools long term. Most of the models will be modified as mentioned above to use simultaneously scheduled non-academic duties so that teachers can swing in and out of the classes, or by scheduling classes together or back to back to allow for integrated delivery. The general comment that the teachers would collectively make is that integration is worth the extra effort both to the students and themselves as professionals, and that the resulting program improvement, especially to science and mathematics, as a result of partnering with technology (vocational education) is extremely important. They would tell you to "try it," and, additionally, that the school system will be greatly improved for the endeavor, because the spin-offs, new interest, and renewal that come with working across disciplines and professionals is a direct outcome. * They have also reported that physics and technology enrollments seem to be going up as a direct result of integration.

Evaluation from a Non-Project Teacher Perspective

In each project school, teachers who were not directly involved in the project were surveyed to determine their feelings and/ or attitudes about integration. Most teachers knew about the integration effort, although some did not. However, many found communication to be poor so that they really did not know specifics about what was occurring until much later in the project. A large majority of non-project teachers were interested and/or excited about integration in both method and content. Generally, most teachers surveyed felt that the attention and priority given the experimental endeavor was appropriate and had major implications for ongoing reform endeavors. They also felt that educational reform should be a high priority. Most felt that change is possible, but identified the roadblocks as well. The roadblocks identified, as you might expect, are administrative support, time, staff and instructor resistance, money, and rigid or traditional mentality; of course, the majority felt that change was possible and a priority. The non-project teachers in the schools seemed to have respect for the project teachers; there seemed to be very little, if any, jealousy, antagonism, or negative feelings about them or their role in the project. Also, most of the teachers surveyed felt that this kind of reform could grow and be sustained long term beyond the project period.

Administrator Evaluation

The administrators evaluated all perspectives of the project. Because of the length and details of their evaluation, it will serve the purpose of this product to indicate their level of support for sustaining integration. The administrators feel collectively that integration is good for the school, program, courses, students, and teachers. The response was collectively "yes" that integration would continue long term in each school involved in the project. And, collectively, additional integration initiatives are occurring in each school.

Student and Parent Evaluation (random responding sample from across schools)

The students' evaluations (responding sample) generally were very positive about the integrated modules and delivery models. They were quite serious in how they felt about seeing and experiencing teachers working together, whether it was in physically delivering integrated courses or in observing them collaborate on integrated content. Students felt strongly that their educational experience was much better when teachers were working together. They were also enthusiastic about the integrated technology activities. They really liked the technological orientation of the integrated activities and the "hands-on" experiences. They more clearly saw the inherent relationships that obviously exist between physics, mathematics, and technology and they mentioned that the reasoning behind the knowledge was more apparent. They collectively (responding sample) indicated that the class was better than what they had heard about or observed as "traditional physics"--more interesting, more related to the real world, and easier (not in rigor) to make sense of. They also indicated that all science classes could benefit from an integrative approach because in grasping the knowledge or concepts those who do not learn as well from books can learn the material as well, and those who do learn well from books learn even more and faster. From their perspective, the "new" and "exciting" was team teaching; the integrated experiments with a technological orientation; the explanation of physics, mathematics, and technology from three different teachers' perspectives; the focus on how industry uses physics; that they were dealing with "beyond" regular physics; "hands-on" to back up the books; field trips; more activities working related to what is being studied instead of simply seeing figures in books; and relevance. Collectively, they indicated that integrated physics, mathematics, and technology should continue to be offered because it is not as boring, they got more help, the activities with technological focus made them feel more "into" the class ("like, actually part of the class"), and they liked the focus on the real world.

Generally, the parents responding to the survey indicated that they thought the integrated method better addressed especially sciences and mathematics because of the technological focus, that the course was more enjoyable, made everything more relevant, and brought realization that mathematics and physics are useful in the real world. They did acknowledge that teachers must have the preparation/planning time and learning time to become a "teaching" team so that lessons would go smoothly in class. They are supportive of more integrative efforts at these schools, could see no real problems with integration and, in fact, strongly support the idea.

External Third Party Evaluation

"The Third Party Evaluator's (TPE) key findings included a strongly positive student and teacher reaction to the approach. Importantly, the participating school administrators also were very supportive of the approach. At most of the sites, it was clear, according to teacher input, that the project achieved its goal of expanding the range of student clientele who could benefit from physics and mathematics. Integration was perceived as such a valuable characteristic that teachers and administrators reported active seeking of alternative means for continuing the project's key features even after the project end brings with it the cessation of outside supplemental funding."

In summary, the project's evaluative focus was one to identify not only the strengths of integration, but the problems and issues as well. Modules and curricula can only be transferred if conceptualized realistically. The evaluation aspect turned out very positive, taking a candid approach to problems and issues.

It is our hope as a project team that the teaching models, curriculum modules, and information discussed here will be helpful. In addition, there is an inservice videotape available that discusses integration issues.

Jule Dee Scarborough
Director/Principal Investigator
April 1, 1992

John C. Shaffer, Ph.D.
Professor of Physics
Northern Illinois University

As a physicist and as a teacher of physics, I was pleased with the opportunity to participate in the project in which these activity units were developed. That participation included critiquing the individual units at a particular stage in their history and offering what, I hope, was some useful advice. The real work was done by the teams of mathematics, technology, and physics teachers who wrote the individual modules and constructed and tested the activities in classrooms and laboratories.

Along with many of my colleagues who teach physics, I have often bemoaned the fact that many, if not most, students who enter a physics course come with no appreciation of the role of physics in understanding the world in which they live and work. They do not make the connection between assigned problems and the actual situations to which these refer. The quantitative modeling and mathematical reasoning which they must apply seems to them unduly laborious as they are unable to connect the textbook exercises with actual experience. What is true for them is surely also true of the larger body of students who encounter physics and other sciences and mathematics in high school curricula. What this project has set out to do and, I believe, to a great extent succeeds, is to provide real-world experiences by exposing the students to a variety of technological devices, systems, and processes. These range from more easily visualized mechanical tools to thermally and optically activated electronic sensors, laser applications, and industrial automation (i.e., robots, machine tools, CAD/CAM). Much technology in the workplace and in the home is hidden from its users and beneficiaries. An integrated approach to understanding the role of basic physics and mathematical reasoning by opening up some of the tools and devices of technology to understand their structure and function in quantitative terms makes great sense. It is an approach which may prove effective in motivating students to make more diligent efforts to understand the connection between science, technology, and mathematics. I am convinced that the teachers who developed the activities in this project have made a contribution to this integration of science, mathematics, and technological education and that the activities they have planned and tested can be utilized, adapted, and expanded for use in a variety of teaching contexts. It can only be helpful in making science, mathematics, and technology more appealing and less remote to more students.

John C. Shaffer
April 1, 1992

LIST OF ACTIVITIES

GRAYSLAKE HIGH SCHOOL

		Inclusive Page Nos.
Activity 1	Laser Burglar Alarm	2-13
Activity 2	Capacitance (RC Time Constant) . . .	14-26
Activity 3	Relative Humidity Sensors (Hygropak Type)	27-41
Activity 4	Variable Resistor (Gas Sensor) . . .	42-52
Activity 5	Industrial Safety (Loudness Sensor and Noise)	53-62
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Activity 8	Hall Effect	89-102
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Activity 10	Photosensitive Devices	118-129
Activity 11	Curved Mirrors	130-156
Activity 12	Sensors in an Automated Industrial System	157-199

ACTIVITY 1: LASER BURGLAR ALARM

TECHNOLOGICAL FRAMEWORK:

The Laser Burglar Alarm is in reality just a light-activated sensor. This same circuitry could be used for a variety of purposes. In many businesses, this circuit is used to count items. As the light beam is interrupted, a counter rather than a transducer is activated. This type of circuit is used in retail establishments to indicate to store personnel when a customer enters the store. The primary importance of this circuit is in the switching action of the transistor. By changing the type of transistors, you could cause the circuit to stay activated once the light beam is interrupted. This would allow for a whole variety of different applications.

PURPOSE:

To determine angles of incident, reflection, and refraction.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
Lasers
Reflection
Refraction
Index of refraction

Technology:
Photocells
Transistors
Relays
Schematic diagrams

Mathematics:
Angles (acute, right, obtuse)
Use of the protractor

PRE-REQUISITES:	Reflection and Refraction
MATERIALS, EQUIPMENT, APPARATUS:	Laser (1mW or better), 12 VDC 1A power supply, ECI bread board, 12 VDC Buzzer (Radio Shack part #273066), 12 VDC Relay (coil resistance of 150-200 ohms, 50-100 mA coil current, Radio Shack part #275-219), Cadmium Sulfide photocell (Radio Shack part #276-1655), 56KΩ 0.5W resistor, 1K 0.5W resistor, .5 in. diameter x 5 in. long hollow tube, connecting wire, NPN switching transistor HFE-200 (Radio Shack part #276-1617), protractor, square or rectangular-shaped transparent piece of glass or plexiglass, flat mirror, and meter stick.
TIME FRAME:	Two 50-minute periods
TEACHING STRATEGIES:	Use the Technology lab or the Physics lab. The Physics teacher will cover the concepts on laser and light, reflection, and refraction. The Technology teacher will cover electronics, schematic diagram reading, the operation of the electrical testing equipment, and the lab orientation.
TEACHING METHODOLOGY:	Students will be grouped (groups of 2-3 are recommended based on equipment available) Lab orientation/demonstration Lab activity Student lab write-ups Post-lab session
FURTHER FIELDS OF INVESTIGATION:	Burglar alarm system, sensor devices

PROCEDURE:

The laser beam is a coherent beam of light. It will keep together over great distances before it begins to disperse. It also keeps a sharp beam upon reflection off of mirrors or passing through transparent material. It is ideal to use a light beam of this sort to bounce around a room or as a burglar alarm. This procedure will begin by setting up the burglar alarm (refer to Figure G-1-1, "Laser Burglar Alarm Wiring Diagram"). Upon completion of the alarm, a test can be performed to demonstrate reflection and refraction.

1. Set the power supply to 12 VDC. Use the multimeter to check proper voltage setting. (After having proper setting, turn the power supply off until step #3.)

2. Use the bread board and set up the components as indicated in the schematic diagram (see Figure G-1-1).

   Note: Conducting wires may need to be soldered on the legs of the NPN switching transistor.

3. After completing component set-up, turn on the power supply. The buzzer should begin to buzz continuously. If the buzzer is not buzzing, check connections and refer again to the schematic diagram for the proper set-up.

4. Turn off the power supply.

5. Place the hollow tube over the photocell. Make sure the tube is parallel to the table and that background light is blocked out from the back of the tube.

6. Place the laser 4 meters away from the hollow tube. Aim the laser light down the center of the hollow tube so it illuminates the photocell.

7. Turn on the power supply. The buzzer should not buzz if the laser is illuminating the photocell. If the buzzer does sound, double check the connections.

8. Keeping the power supply on, block the light beam from the laser. The buzzer should begin to buzz once the light path is interrupted and stop buzzing once the light path is restored to illuminate the photocell.

   Why does the buzzer begin to buzz when the light beam path is interrupted?________________________
   ____
   ____
   ____

9. Take two chalk board erasers and pound them together in the path of the laser light (be sure there is chalk dust on the erasers). Why are you able to see the beam path now?______________
   ____
   ____
   ____

10. Turn off the power supply. Move the laser as diagramed in Figure G-1-2 ("Laser Burglar Alarm Relative Position") so there is a right angle between the laser light path and the reflected light path to the photocell. The laser should be 2 meters from the mirror and the mirror 2 meters from the photocell.

11. Keeping the power supply off, measure the angle of incident made by the approaching laser light path to the mirror. Measure the angle of reflection made by the laser light as it reflects off of the mirror. Record the angles to the nearest degree.

    angle of incident_________

    angle of reflection_______

    What is the relationship between the two angles measured? ______________________________________
    ____
    ____

12. Place a square or rectangular transparent piece of glass or plexiglass between the laser and the path to the mirror. The glass should be thick enough to allow the laser light to pass through it. Make sure the laser light strikes the plexiglass at a right angle (perpendicular to the plexiglass). Also check to be sure the reflected laser light is illuminating the photocell.

13. Turn on the power supply. Slowly rotate the plexiglass 1/4 to 1/3 turn. What happens to the light beam from the laser?________________________

Does the buzzer sound?___________ Explain why___

What happens to the speed of light as it passes from a less dense medium air into a more dense medium glass?________________________________

ANTICIPATED PROBLEMS:

There could be problems with the wiring diagram. Check all connections. The NPN switching transistor HFE = 200 Radio Shack part #276-1617 must be used or a compatible transistor. The relay may need to have wires soldered on to it. Other parts may also need wires soldered on to make electrical connections. Make sure the photo cell is placed inside a hollow tube. This will prevent any background light disturbance from closing the relay. Make sure the laser light is directed down the tube for the system to operate and to illuminate the photo cells.

METHODS OF EVALUATION:

Observation during the lab activity

Post-lab write-up

Selected quiz items on the unit test

FOLLOW-UP ACTIVITIES:

Through your school's career placement center, arrange to have a guest speaker from a laser or optical company or security alarm system company make a presentation. Students could do a library report on other uses of lasers. A field trip to a place where lasers are used would be beneficial.

REFERENCES, RESOURCES, VENDORS:

Energy Concepts, Inc.
7740 N. Long Avenue
Skokie, IL 60077
(708) 283-4422

Aidex Corporation
1802 N. Division St.
Morris, IL 60450
(800) 251-9935

Radio Shack

For laser:
Central Scientific Company
11222 Melrose Ave.
Franklin Park, IL 60131-1364
(708) 451-0150

Science Kit & Bonreal Labr.
777 East Park Drive
Tonawanda, NY 14150-6784
(800) 828-7777

Sargent-Welch
P.O. Box 1026
Skokie, IL 60076-1026
(800) 721-4368

Fisher Scientific-EMD
4901 W. LeMoyne Street
Chicago, IL 60651
(800) 621-4769

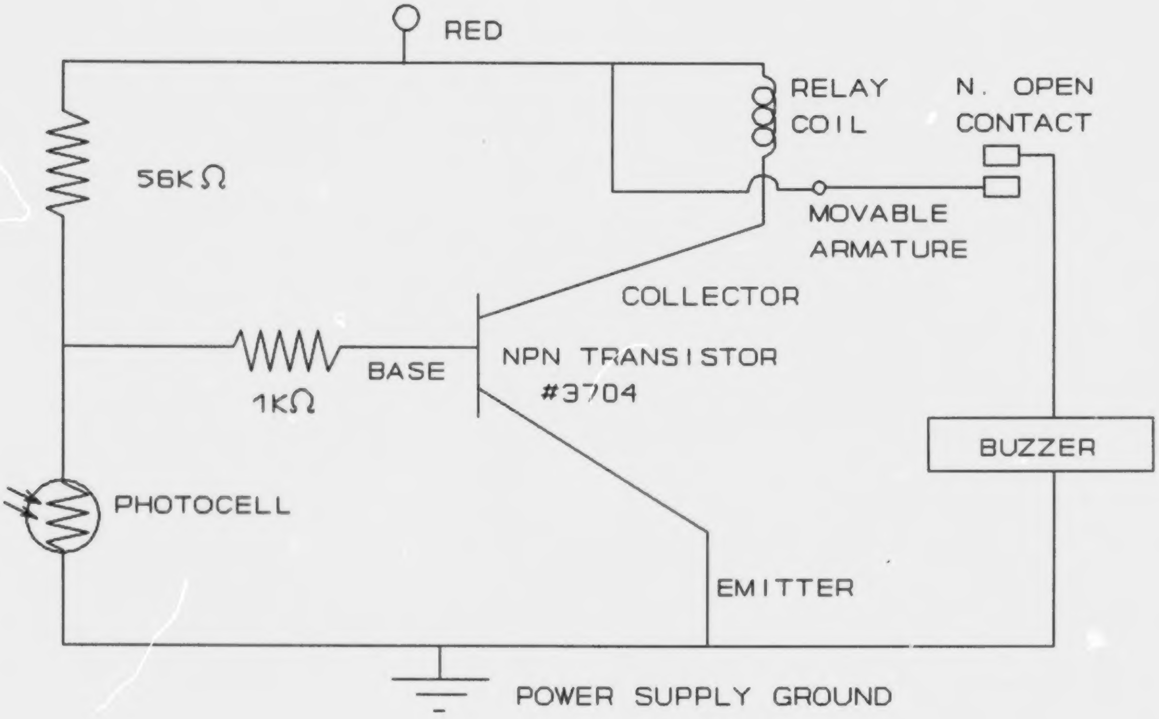

RED
RELAY
COIL
N. OPEN
CONTACT
56KΩ
MOVABLE
ARMATURE
COLLECTOR
BASE
NPN TRANSISTOR
#3704
1KΩ
BUZZER
PHOTOCELL
EMITTER
POWER SUPPLY GROUND

Figure G-1-1

Laser Burglar Alarm Wiring Diagram

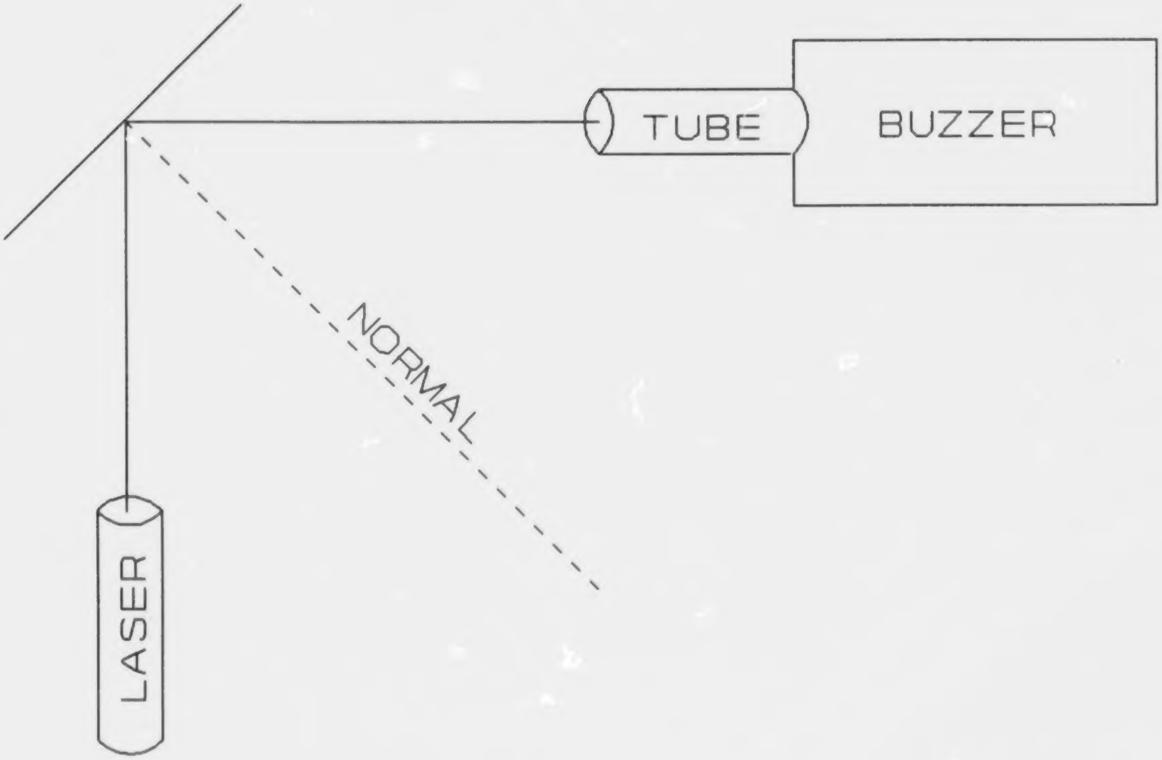

TUBE
BUZZER
NORMAL
LASER

Figure G-1-2

Laser Burglar Alarm Relative Position

LASER BURGLAR ALARM POST-LAB QUESTIONS

1. State the Law of Reflection.

2. What is the definition of illumination?

3. What is optical refraction?

4. What is the meaning of the index of refraction?

5. If light passed from air into glass, what would be the speed of light in glass? (Look up the index of refraction for glass and air.)

6. What is Snell's Law?

LASER BURGLAR ALARM MATHEMATICS WORKSHEET

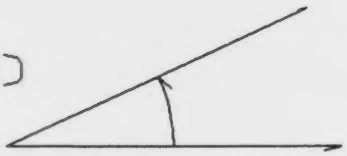
1. Define an acute angle.

2. Define a right angle.

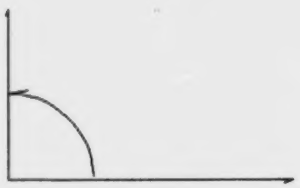
3. Define an obtuse angle.

4. Measure the following angles to the nearest degree using a protractor:

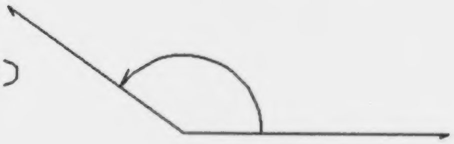
a)



b)



c)



ACTIVITY 2: CAPACITANCE (RC Time Constant)

TECHNOLOGICAL FRAMEWORK:

In a resistive capacitance (RC) circuit, the length of time between its charge and discharge is determined by the values of the capacitors and resistors. As these values increase, so does the charge-discharge period (time constant). The actual charge or discharge in an RC circuit is exponential in nature. It may be used to determine the frequency of flashes in a flashing light or frequency of soundings of an alarm horn.

The spontaneous breakdown or decay of an unstable atomic nucleus is used in reactors in nuclear electric power plants to convert atomic energy into electrical energy. The amount of time it takes for one-half of a given element to go through a decay process is called its "half-life." Atomic decay is also exponential in nature.

Another example of an exponential process is population growth. The number of individuals added to the population during each time period increases exponentially.

PURPOSE:

To demonstrate the timing effect of different-sized capacitors in an RC circuit.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics/Technology:
Capacitance
RC time constant
RC circuits
Dielectric materials

Mathematics:
Natural logarithms

PRE-REQUISITES:

Resistance
Use of electrical testing equipment
Series-parallel circuits
Capacitance
Dielectric materials
Uses of Electronics Workbench (EWB) software

MATERIALS, EQUIPMENT, APPARATUS:

Capacitors and resistors
Power supply
Signal generator
EWB software (IBM)
IBM computer or compatible
Oscilloscope
Multimeters
Neon lamp

TIME FRAME:

Two 50-minute periods

TEACHING STRATEGIES:

Use the Electronics lab.

Mathematics teacher will cover geometric sequences and the natural logarithm.

Physics teacher will cover capacitance and dielectrics.

Technology teacher will cover RC circuits and the RC time constant; supervise the lab.

TEACHING METHODOLOGY:

Review math and physics pre-requisites

Review operation of electrical testing equipment

Lab demonstration

Lab activity

Post-lab session and write-ups

FURTHER FIELDS OF INVESTIGATION:

Emergency vehicles using strobes to change traffic signals

Timing devices

Balancing of stereo circuits

CAPACITANCE PROCEDURE:

By connecting an RC circuit as shown in this activity, it will be possible to calculate and measure the time constant as it changes with both resistance and capacitance. It will be possible to visually see the effect of changing the size of the components. The use of an RC circuit with a neon lamp will demonstrate how an RC circuit can be used to time the flashing of the lamp.

Part I. Using Electronics Workbench (EWB)

A. Use EWB Analog to create an RC circuit as in Figure G-2-1 ("RC Circuit Wiring Diagram").

B. Connect the signal generator + to "A" and ground to "C". Set the square waveform at 1.0 V and 400 Hz.

C. Connect the oscilloscope (scope) channel A to "A" and ground to "C".

D. Set the time base to 0.2 mS/Div and the channel A voltage to 0.2V/Div, AC.

E. Activate the circuit and sketch the displayed waveform from the scope (sketch goes in Table G-2-1, "Waveform/Time Constant Data."

F. Repeat steps A and E for four additional circuits using the following values:

Trial #	Resistor	Capacitor
1	27 KΩ	0.01 μF
2	10 KΩ	0.02 μF
3	10 KΩ	0.005 μF
4	4.7 KΩ	0.01 μF

G. Calculate the time constant for Figure G-2-1 and trials 1-4 and record in Table G-2-1.

Part II. Using Electrical Testing Equipment

A. Using the electrical testing equipment and components, create the RC circuit as seen in Figure G-2-1.

B. On the scope, measure the voltage at 1 time constant (record in Table G-2-1).

C. Repeat steps A and B using the values for trials 1, 2, 3, and 4.

Part III. Voltage Across the Capacitor

Calculate the voltage across the capacitor (V_c) using the formula:

$$V_c = V_{in} - V_{in}e^{(-t/\tau)}; \ \tau = R\,C$$

Note. Because the time (t) equals 1 time constant, you will use e^{-1} in the formula.

Record the calculated voltage (V_c). (The calculated voltage should be close to the measured voltage in Part II.)

V_c = ___________

Part IV. Strobe Effect

A. Connect a neon lamp in the circuit as shown in Figure G-2-2 ("RC Neon Lamp Circuit Wiring Diagram").

B. Increase the voltage of the power supply until the neon lamp flashes.

Record the voltage from the multimeter.

V = ___________

C. Observe the voltage reading as the neon lamp continues flashing. What happens to the voltage?____

____

____

D. Set the scope Time/Div setting at 10 mS and the Volts/Div setting at 2.

Record the high voltage from the scope.

____

Record the low voltage from the scope.

____

What is the voltage difference?

____

Note. The high voltage is the voltage it takes to cause the lamp to conduct current. Once the lamp has fired, it will continue to conduct current until it reaches the low voltage. The lamp will not conduct current again until the capacitors have charged to the high voltage.

ANTICIPATED PROBLEMS: It is necessary to have a variety of capacitors and resistors in stock.

METHODS OF EVALUATION: Observation during the lab activity

Post-lab write-up

Selected quiz items on the Unit Test

FOLLOW-UP ACTIVITIES:

Build a stroboscope using a kit and then attempt to calibrate it to determine various frequencies. Watch the film "Nuclear Energy: The Question Before Us" produced by National Geographic (Video #51159; 16mm Film #50072). The film will explain how tiny uranium fuel pellets are converted into vast amounts of energy. The film will also discuss waste disposal and radioactivity concerns. This is an excellent tie-in with exponential functions, such as the RC time constant. The class could also take a field trip to a nuclear power plant. Have the tour guide explain radioactive decay and safety standards in regard to radiation. Visit an electrical manufacturing facility to learn more on the use of RC circuits.

REFERENCES, RESOURCES, VENDORS:

Electricity/Electronics texts

Stereo manufacturer

Timing device manufacturer

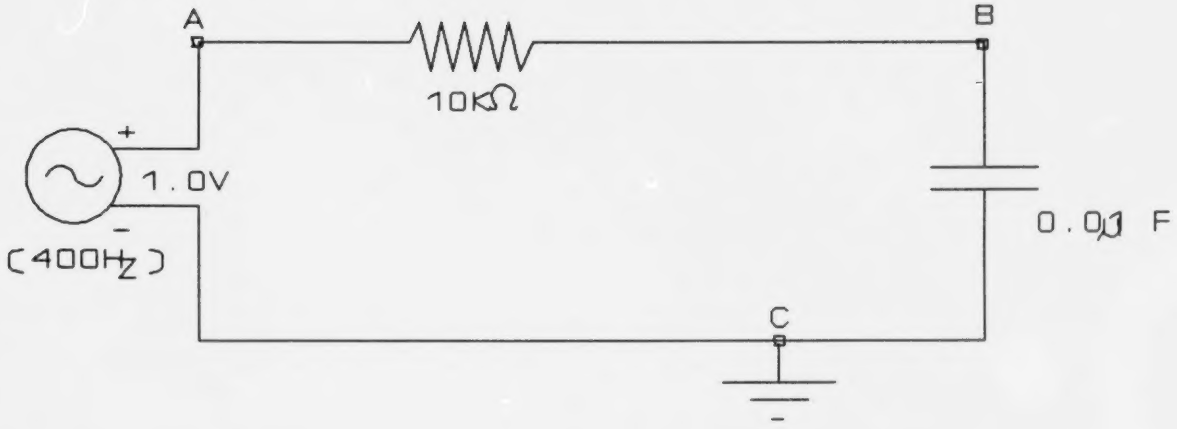

A
B
C
10KΩ
+
−
1.0V
(400Hz)
0.0µ1 F

Figure G-2-1

RC Circuit Wiring Diagram

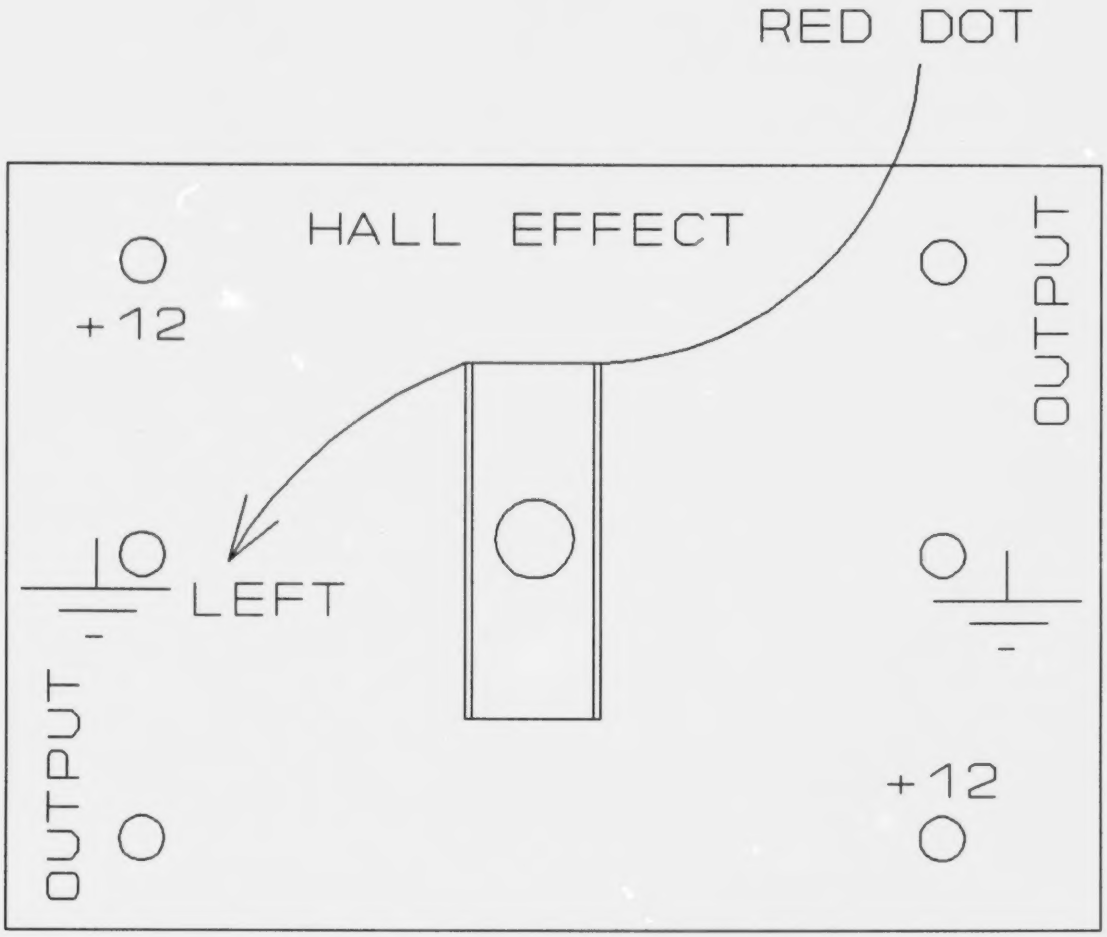

RED DOT
HALL EFFECT
+12
OUTPUT
LEFT
−
−
OUTPUT
+12

Figure G-2-2

RC Neon Lamp Circuit Wiring Diagram

Table G-2-1

Waveform/Time Constant Data

Trial #		Waveform Sketch	T = RC	Scope Voltage at T
Fig.	+V			
	-V			
1	+V			
	-V			
2	+V			
	-V			
3	+V			
	-V			
4	+V			
	-V			

CAPACITANCE POST-LAB QUESTIONS

1. What is a time constant?

2. What effect did increasing the resistance have on the time constant?

3. What effect did increasing the capacitance have on the time constant?

4. What effect does a capacitor have on the voltage in a circuit?

5. Define a dielectric material.

6. Calculate V_c using $V_c = V_{in} - V_{in}e^{(-t/\tau)}$
   when $t = 0.4$ s and $\tau = 25 \times 10^{-6}$ s.

CAPACITANCE MATHEMATICS WORKSHEET

Natural Logarithm:

Base e, where $e = (1 + 1/k)^k$

As k grows without bound, the value of approaches 2.7183 .....

Exponential Growth: $y = ae^{nt}$ (to raise e to a power on a calculator, use the **EX** key.)

Problem 1

A quantity grows exponentially at the rate of 2% per minute. By how many times will it have increased after 4 hours?

t = 4 hours = 240 minutes

N = 2% = .02 a = initial value

$$y = ae^{nt} = ae^{0.02(240)}$$

$$\frac{y}{a} = e^{0.02(240)}$$

$\frac{y}{a} = ?$; [raise e to the power $^{0.02(240)}$]

Problem 2

If the world population were 4 billion in 1975 and grew at an annual rate of 1.7%, what would be the population in 1992?

t = ? years; N = 1.7% = 0.17; a = 4 billion

$$y = ae^{nt} = 4e^{.017(\ ?\ )}$$

y = ?

Exponential Decay: $y = ae^{-nt}$

Problem 1

A room initially 80°F above the outside temperature cools exponentially at the rate of 25% per hour. Find the temperature of the room (above the outside temperature) at the end of 135 minutes.

t = 135 min. = 2.25 hours

a = 80

n = 25% = .25 $\qquad$ $y = 80e^{-0.25(2.25)} = ?$

Problem 2

A current decays from an initial value of 300 mA, at an exponential rate of 20% per second. Find the current after 7 s. (Time constant is the reciprocal of n: T = 1/n)

n = 0.20; a = 300 mA

T = 1/0.20 = 5 s

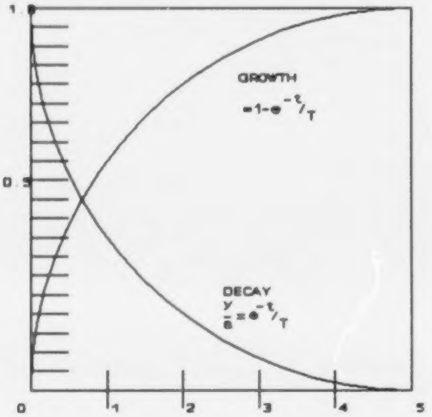
t = 7 s $\qquad$ t/T = 7/5 = 1.4 time constants

$y = ae^{-nt} = 300\ e^{-0.20(7)} = 300\ e^{-1.4}$

Note. -nt is same as -t/T

$y = 300\ e^{-1.4} = ?$ mA

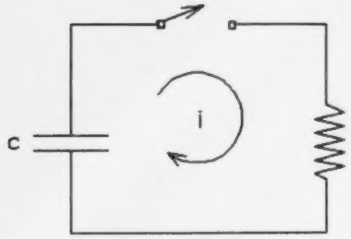
Universal Growth and Decay Curves



Problem 3

When a capacitor C, charged to a voltage E, is discharged through a resistor R, the current i will decay exponentially according to the equation:

$$i=\frac{E}{R}e^{-t/RC}$$

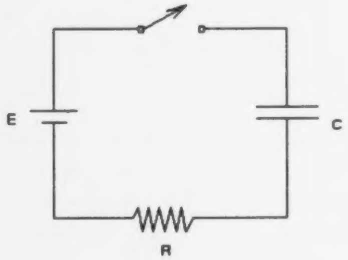


Find the current after 45 ms (milliseconds) in a circuit where E = 220 V, C = 130 microfarads, and R = 2700Ω.

Problem 4

When a fully discharged capacitor C is connected across a battery, the current i flowing into the capacitor will decay exponentially according to the equation:

$$i=\frac{E}{R}e^{-t/RC}$$



If E = 115 V, R = 350Ω, and C = -0.00075 F,

Find the current after 75 ms.

ACTIVITY 3: RELATIVE HUMIDITY SENSORS (Hygropak Type)

TECHNOLOGICAL FRAMEWORK:

In many industrial applications, the relative humidity in a facility is critical to the operation of the facility. For example, excessive humidity in the screen printing industry can cause the destruction of the screens. A lack of humidity in paper handling facilities causes excessive static electricity which can be dangerous. The accurate measurement of humidity in drying operations saves large amounts of energy. Newer model clothes dryers have sensors that can determine the humidity level within the dryer. There are many other instances where accurate measurement of humidity is critical.

PURPOSE:

To demonstrate the change in resistance with change in humidity by using a Hygropak humidity sensor.

To calibrate the humidity sensor using known values of humidity.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:	Mathematics:
Ohm's Law	Graphing
Humidity	Slope
Conductivity	Direct variation
Relative humidity	Inverse variation

Technology:
Humidity: Measurement & control

PRE-REQUISITES:	Introduction to the use of electrical testing equipment
MATERIALS, EQUIPMENT, APPARATUS:	Power supply Multimeters Hygropak humidity sensor with 10 MΩ resistor wired in series Paper cups Humidity gauge
TIME FRAME:	One 50-minute period
TEACHING STRATEGIES:	Students grouped by threes or fours. Use the Electricity lab. Technology teacher will explain the use of the meters and how the humidity sensor functions. Mathematics teacher will review graphing, direct variation, and inverse variation. Physics teacher will cover Ohm's Law, relative humidity, and conductivity.
TEACHING METHODOLOGY:	Review the physics and math concepts Show electrical equipment set-up Introduce Ohm's Law Lecture and demonstration on humidity sensors Lab activity Post-lab session, write-up, and graphs

FURTHER FIELDS OF INVESTIGATION:

Alarm circuits
Paper manufacturing
Data processing facilities
Printing operations
Grain dryers
Atmospheric control

PROCEDURE:

Humidity is a measure of the amount of water vapor in the air. The Hygropak sensor is a device that detects conducting particles (moisture). As the level of moisture on the surface of the sensor increases, the resistance between the interlaced metal fingers mounted on the printed circuit board decreases. Since the metal fingers are spaced very closely together, a small change in the moisture level can be easily detected by a corresponding change in the resistance level.

Part I of this activity uses an ohmmeter to measure the resistance across the Hygropak sensor for several different trials. Part II of this activity uses a voltmeter to illustrate how a voltage can be controlled by changes in the humidity level. Part III uses the Hygropak sensor coupled with a humidity gauge to demonstrate relative humidity (% of water vapor in the air compared to the maximum amount it could contain at standard temperatures and pressure) in relationship to resistance over a five-day period of time.

Part I. Sensor Resistance

A. Mount the sensor alone in the circuit. Set the ohmmeter to the Rx100KΩ or Megohm setting. (See Figure G-3-1, "Humidity Sensor/Ohmmeter Wiring Diagram.")

B. Without touching or breathing on the sensor, measure the resistance across its terminals. (Record in Table G-3-1, "Humidity Sensor Resistance/Voltage Data.")

C. Breathe on the sensor and watch the ohmmeter change. (Record the resistance in Table G-3-1, Trial #2.)

D. Moisten a 1" square piece of paper towel and allow it to become fairly dry. Place it in a paper cup. Place the cup over the sensor. (Record the resistance in Table G-3-1, Trial #3.)

E. Moisten a piece of paper towel large enough to make a ball to fit in the bottom of the cup. Ball up the wet paper and stick it to the bottom of the cup. Place the cup over the sensor. (Record the resistance in Table G-3-1, Trial #4.)

F. Wet a 3 cm square piece of paper towel and place it directly on the sensor. (Record the resistance in Table G-3-1, Trial #5.)

Part II. Voltage Change

A. Using the 10 MΩ resistor, Hygropak sensor, power supply, and multimeter, wire the circuit as shown in Figure G-3-2, "Humidity Sensor/ Voltmeter Wiring Design."

B. Activate the circuit. Measure the voltage across the terminals, being careful not to touch or breathe on the sensor. (Record the voltage in Table G-3-1, Trial #1.)

C. Repeat steps C through F in Part I. (Record the voltage in Table G-3-1, Trials #2-#5.

Part III. Calibration

A. Using a manufactured humidity gauge, measure the relative humidity in the classroom.

B. With the humidity sensor set up as in Part I, record the resistance of the sensor at the same time you use the manufactured gauge to read the humidity. (Record under Day #1 in Table G-3-2, "Humidity Sensor-Humidity/Resistance Data.")

C. Repeat this procedure at the beginning of the period for the next four days. (Record in Table G-3-2 under Days #2-#5.)

(After a week of readings, you should begin to see that a certain resistance equals a certain humidity level. If you could vary the humidity level between 0% and 100%, you would be able to develop a complete chart of resistances for each different level of humidity.)

D. Using a sheet of graph paper, graph resistance as a function of voltage. (Draw a line through the plotted points and calculate the slope.)

E. Using a sheet of graph paper, graph resistance as a function of humidity. (Draw a line through the plotted points and calculate the slope.

ANTICIPATED PROBLEMS: If the Hygropak sensor gets saturated with water, this could throw off the measurements taken from that time on.

METHODS OF EVALUATION:

Observation during the lab activity

Pre-lab quiz

Post-lab write-up

Selected quiz items on the Unit Test

FOLLOW-UP ACTIVITIES:

Have students record the outside ambient humidity using the sensor each day for the entire year.

Have an alarm company representative speak to the class to explain the use of sensors and give a demonstration on how they operate.

REFERENCES, RESOURCES, VENDORS:

Energy Concepts, Inc.

Aldex Corporation

Electrical supply houses

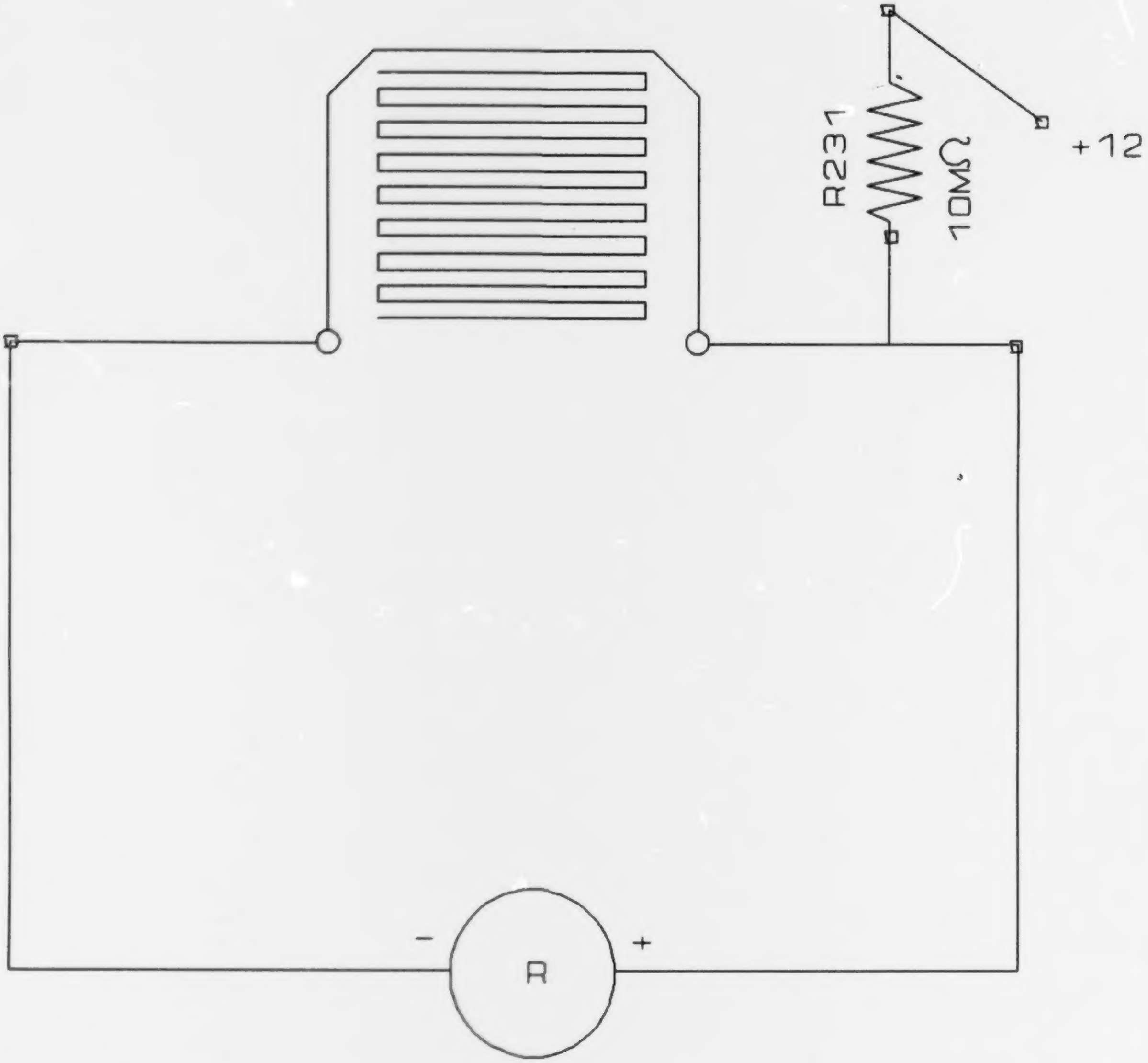


Figure G-3-1

Humidity Sensor/Ohmmeter Wiring Diagram

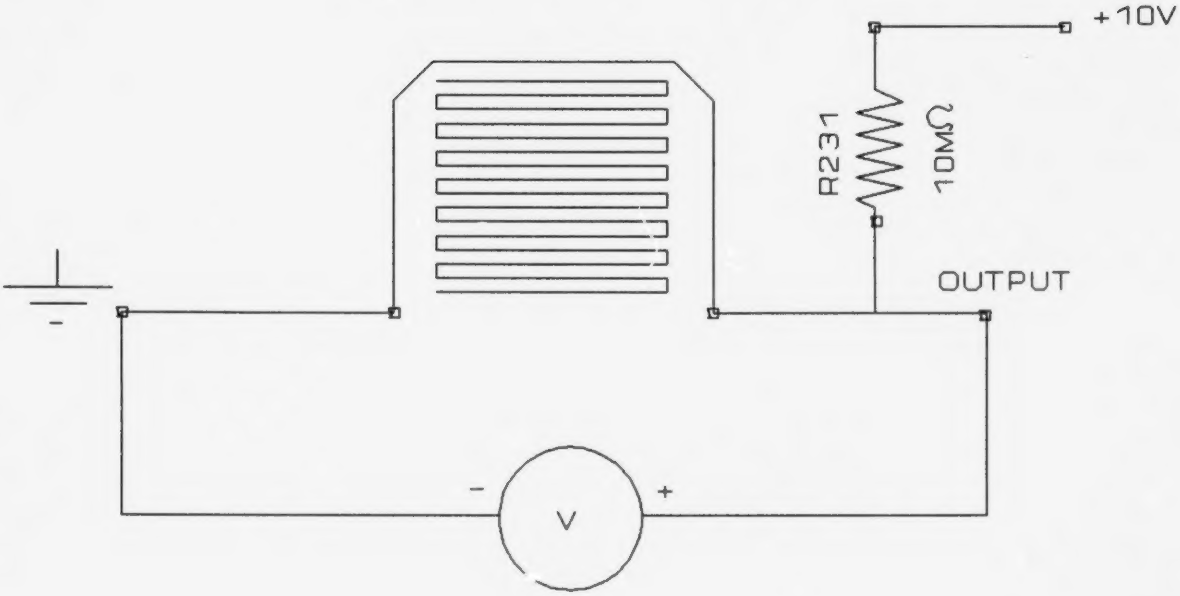


Figure G-3-2

Humidity Sensor/Voltmeter Wiring Diagram

Table G-3-1

Humidity Sensor Resistance/Voltage Data

Trial #	Resistance	Voltage
1		
2		
3		
4		
5		

Table G-3-2

Humidity Sensor-Humidity/Resistance Data

Day #	% of Humidity	Resistance
1		
2		
3		
4		
5		

RELATIVE HUMIDITY SENSORS POST-LAB QUESTIONS

1. What happens to the voltage across the Hygropak sensor when the humidity increases?

2. Does the resistance increase as the humidity increases?

   Is the type of change in the resistance an example of a direct variation or an example of an inverse variation?

3. Give two examples where a humidity sensor could be used.

4. What conclusions can be drawn from the data as collected in Table G-3-2?

PHYS-MA-TECH
AN INTEGRATED PARTNERSHIP

RELATIVE HUMIDITY SENSORS MATHEMATICS WORKSHEET

Part A. Direct Variation Review

$$y=k_x \text{ or } \frac{y}{x}=k$$

"y varies directly as x" with k as the constant of proportionality.

$$\frac{y_1}{x_1} = \frac{y_1}{x_2} = k$$

direct proportion

Practice:

1. If y varies directly as x, and y is 56 when x is 21, find y when x is 74.
2. If y is directly proportional to x, and y has a value of 88.4, when x is 23.8:
   (a) Find the constant of proportionality.
   (b) Write the equation $y = k_x$
   (c) Find y when x = 68.3.
   (d) Find x when y = 164.

Application:

1. The resistance of a conductor is directly proportional to its length. If the resistance of 2.6 mi of a certain transmission line is 155Ω, find the resistance of 75 mi of that line.

2. The resistance of a certain spool of wire is 1120Ω. A piece 10 m long is found to have a resistance of 12.3Ω. Find the length of wire on the spool.

Part B. Inverse Variation Review

$$y = k(\frac{1}{x}) \text{ or } xy = k$$

"y varies inversely as x" with k as the constant of proportionality.

$$x_1y_1 = x_2y_2 = k$$

$$\frac{y_1}{x_2} = \frac{y_2}{x_1}$$

inverse proportion

Practice:

1. If y varies inversely as x, and y is 385 when x is 832, find y when x is 226.
2. If y is inversely proportional to x, and y has the value 104 when x is 532:
   - (a) Find the constant of proportionality.
   - (b) Write the equation $y=k(\frac{1}{x})$
   - (c) Find y when x is 668.
   - (d) Find x when y is 226.

Application:

1. The current in a resistor is inversely proportional to the resistance. By what factor will the current change if a resistor increases 10% due to heating?

2. The resistance of a wire is proportional to the square of its diameter. If an AWG size 12 conductor (0.0808 in. diameter) has a resistance of 14.8Ω, what will be the resistance of an AWG size 10 conductor (0.1019 in. diameter) of the same length and material?

Supplement on the TI-81 Calculator

For two-variable data, the STAT CALC menu has four regression models for curve fitting and forecasting. The X value is interpreted as the independent variable and the Y value as the dependent variable.

To enter DATA in pairs, you use **2nd Matrix** and use the right arrow to select **DATA**. You want to use **1:Edit**, so just use the **Enter** key. Next, you enter the DATA in pairs for x1, y1, etc.

To clear the screen, you use **2nd Clear**. Now use **2nd Matrix** again and select Draw. Choose **2:Scatter** followed by **Enter**. You will see a scattering of your points. To clear a drawing, you use **2nd PRGM** and select **1:CirDraw** and **Enter**.

To calculate the results of your data, press **2nd Matrix** to display the STAT CALC menu. Choose the type of regression model you think might fit the scatter plot you saw earlier. To calculate a linear regression mode, select **2:LinReg**. To calculate a logarithmic regression model, select **3:LnReg**. To calculate an exponential regression, select **4:ExpReg**. To calculate a power regression model, select **5:PwrReg**.

Model	Formula	Restrictions
Linear	$Y = a + bX$	
Logarithmic	$Y = a + bin(x)$	All X values > zero
Exponential	$Y = ab^x$	All Y values > zero
Power	$Y = aX^b$	All X and Y > zero

The TI-81 calculates the values for a and b according to the selected regression model. In addition, the TI calculates r, the correlation coefficient, which measures the goodness of the fit of the equation with the data. In general, the closer r is to 1 or -1, the closer r is to zero, the worse the fit.

Sample to try out ...

```
2nd Matrix Data <enter>
     3, 15, 4, 19, 2, 11, 5, 26, 6, 28
2nd Clear
2nd Matrix Draw 2: <enter>
((Study the scatter plot closely))
Clear Clear
2nd Matrix 2:<enter>         ****record the a, b, and r values
((repeat for 3:, 4:, and 5:))
```

Which one best fits the scatter plot?

What would be your estimate for X = 10?

ACTIVITY 4: VARIABLE RESISTOR (GAS SENSOR)

TECHNNOLOGICAL FRAMEWORK: Many industrial facilities work with flammable liquids, which when vaporized become explosive. Detecting the presence of these explosive vapors is critical to the safe operation of their facilities. Probably the most visible area where explosive gases come into play is mining. Many lives could have been saved in the past if miners had a better method of detecting explosive vapors. The natural gas companies add an odor to the gas to help consumers detect its presence. Without a viable gas sensing system, many more lives would be lost, as well as many more industries destroyed.

PURPOSE: To demonstrate the gas sensor as a variable resistor due to gas vapor.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The social and environmental implications and technological development.
- The principles of scientific research and their application in simple projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
Ohm's Law
($V = IR$)

Mathematics:
Formula manipulation

Technology:
Bridge networks
Coefficients of resistance

PRE-REQUISITES:	Ohm's Law Resistance Voltage Current
MATERIALS, EQUIPMENT, APPARATUS:	Power supply; circuit panel Digital multimeter; gas/humidity module Assorted gases, (e.g., ammonia, paint, white-out, acetone, gasoline, lighter fluid, bug spray, cleaning fluid, paint thinner) Caution: Gases are extremely dangerous and toxic. Avoid breathing fumes of fluids or gases. Consult the teacher before using any fluids or gases.
TIME FRAME:	One 50-minute period
TEACHING STRATEGIES:	Group students by threes. Use the Physics/ Electricity lab. Mathematics teacher will assist in the lab. Physics teacher will cover Ohm's Law. Technology teacher will cover operation of electrical testing equipment and the lab orientation.
TEACHING METHODOLOGY:	Review of the physics concepts Review use of the testing equipment Lab activity Post-lab session and write-up
FURTHER FIELDS OF INVESTIGATION:	Gas sensors used in industry

PROCEDURE:

This lab activity will deal with the use of a Tauguchi gas sensor. The sensor works using the concept of negative temperature coefficient of resistance. When the temperature of the device increases, the resistance decreases. The sensor consists of a ceramic tube coated with N-type powder. As gas is absorbed by the powder, it fills the voids between the grains, thus reducing the resistance. This process does not work well at low temperatures as the resistance is very high. To reduce the resistance, the sensor is heated to approximately 200° C. This heating reduces the resistance considerably. The combined effects of the heating and the introduction of a flammable gas allow for a measurable change in the resistance, which in turn can be adapted to a safety system.

A multimeter will be connected across a 4.7 KΩ resistor and the voltage will be read. The use of Ohm's Law will give the current in mA for each fluid or gas used in the activity. Comparisons of the currents will be made.

Part I. Resistance Across the Gas Sensor

A. Set the DC power supply to 5 VDC output. Connect the voltage leads and ohmmeter (ohms) as shown in Figure G-4-1 ("Gas Sensor/Ohmmeter Wiring Diagram").

B. With the power supply OFF, measure the resistance of the sensor with the meter across the gas sensor (+24 and output).

R_c = __________MΩ (cold resistance)

C. With the power supply ON, the resistance will be very low. Allow for the resistance to stabilize* (several minutes). When stabilized, record the resistance.

R_H = __________MΩ (hot resistance)

*The resistance may not fully stabilize.

D. With the supervision of an instructor, proceed to apply a fluid to a piece of paper or tissue. Wave the paper or tissue over the top of the sensor. Measure and record the resistance when a fluid is present. Use several of the fluids shown in Table G-4-1 ("Gas Sensor-Fluid/ Resistance").

Part II. Voltage Across a 4.7 KΩ load

A. Connect the 6V and 5V power supplies along with a voltmeter as shown in Figure G-4-2 ("Voltmeter Wiring Diagram").

B. Turn ON the power supplies and the meter. When the voltage appears to have stabilized, record the minimum voltage across a 4700Ω resistor.

V_{min} = ____________

C. Calculate the current flow through the 4700Ω resistor. (I = V/R)

I = ____________mA

D. Using the fluids obtained from the instructor, measure the voltage for each and calculate the current flow through the 4700Ω resistor. Record the data in Table G-4-2 ("Voltmeter Wiring Diagram").

ANTICIPATED PROBLEMS:

Stabilizing the sensor's resistance

Stabilizing the voltage

METHODS OF EVALUATION:

Observation during the lab activity

Post-lab write-up

Quiz items on Ohm's Law on the Unit Test

FOLLOW-UP ACTIVITIES:

Connect a light bulb to the circuit and as resistance changes and voltage increases, the bulb will light.

Have a guest speaker give a presentation on gas sensors.

Discuss why and where gas sensors are used.

REFERENCES, RESOURCES, VENDORS:

Energy Concepts, Inc.
7740 No. Long Ave.
Skokie, IL 60077
(708) 283-4422

Aidex Corporation
1802 N. Division St.
Morris, IL 60450
(800) 251-9935

A local hardware store

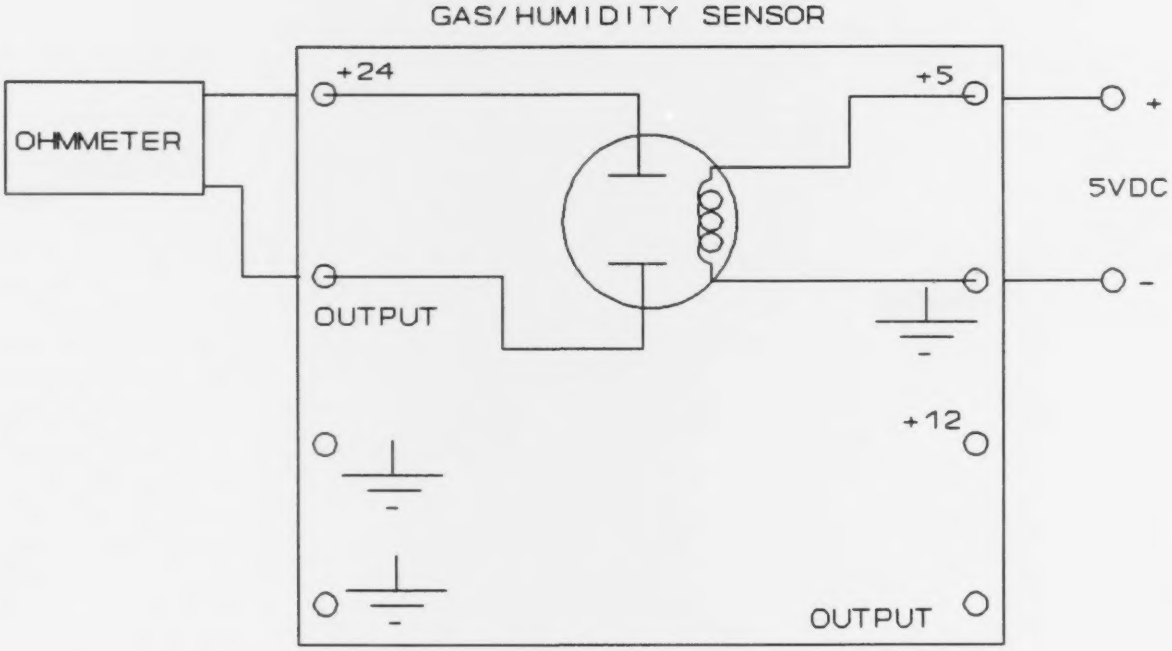

GAS/HUMIDITY SENSOR
OHMMETER
+24
OUTPUT
+5
+
5VDC
-
+12
OUTPUT

Figure G-4-1

Gas Sensor/Ohmmeter Wiring Diagram

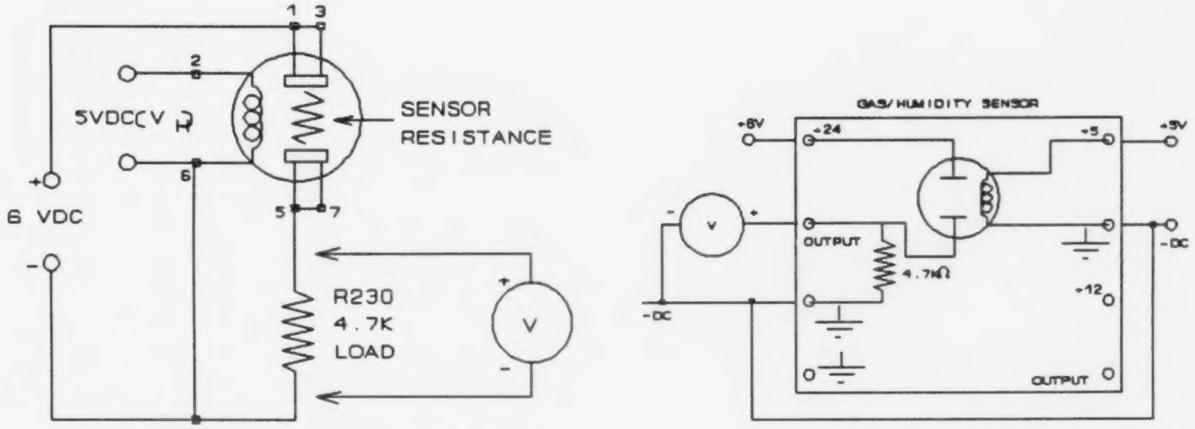

1
3
2
5VDC(V
H
SENSOR
RESISTANCE
6
+
6 VDC
-
5
7
R230
4.7K
LOAD
+
V
-
GAS/HUMIDITY SENSOR
+6V
+24
-5
+5V
-
V
+
OUTPUT
4.7kΩ
-DC
-12
-DC
OUTPUT

Figure G-4-2

Voltmeter Wiring Diagram

Table G-4-1

Gas Sensor-Fluid/Resistance

Fluid	Resistance
ammonia	
white-out	
acetone	
gasoline	
lighter fluid	
bug spray	
cleaning fluid	
paint thinner	

Table G-4-2

Voltage/Current Data

Fluid	Voltage (v)	Current (mA)
ammonia		
white-out		
acetone		
gasoline		
lighter fluid		
bug spray		
cleaning fluid		
paint thinner		

VARIABLE RESISTOR POST-LAB QUESTIONS

1. Compare the current calculated flow for each fluid.
    (a) Which fluid had the highest current flow?
    (b) Which fluid had the lowest current flow?

2. Why do sensors need to be used to detect gas leaks?

3. Why is the cold resistance much higher than the hot resistance?

4. The resistance in a sensor is 252 KΩ. The sensor is switched on and a voltage of 12 volts is measured across the sensor. What is the current flow in the sensor?

    I = __________mA; I = __________A

5. Name two local industries which would have gas sensors installed for safety reasons.

VARIABLE RESISTOR MATHEMATICS WORKSHEET

A formula is a literal equation that relates two or more mathematical or physical quantities. These are the equations that describe the workings of the physical world.

To solve a literal equation means to "isolate" one of the letters on one side of the equal sign.

Samples To Be Solved:

1. The formula for the amount of heat q flowing by conduction through a wall of thickness L, conductivity K, and cross-sectional area A is:

   $$q=\frac{kA(t_1-t_2)}{L}$$

   where t_1 and t_2 are the temperatures of the warmer and cooler sides, respectively. Solve this literal equation for t_1.

2. Solve the literal equation in #1 for A.

3. The formula for the displacement d of a freely falling body having an initial velocity V_o and acceleration a is:

   $$d=V_ot + 1/2\ at^2$$

   Solve this literal equation for a.

4. Solve the literal equation in #3 for V_o.

ACTIVITY 5: INDUSTRIAL SAFETY (LOUDNESS SENSOR AND NOISE)

TECHNOLOGICAL FRAMEWORK:

With the advent of the Occupational Safety and Health Act (OSHA), the amount of noise workers are subjected to became an important topic. Many workers were losing their hearing, either through tone deafness or general hearing loss. In the long run, this meant years of lost productivity for a company, usually with their most highly skilled employees. By having a better understanding of the effects of sound and the intensity of sound on the human ear, designers may better design equipment and systems that will further deter loss of hearing in the workforce.

PURPOSE:

To distinguish between noise, music, and a single frequency.

To measure the sound intensity of various types of industrial equipment.

To plot sound intensities using a decibel scale.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The social and environmental implications and limitations of technological development.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:	Physics: Sound intensity Frequency Waveforms	Mathematics: Circles Graphing functions Parabola Logarithm
	Technology: Noise pollution	
PRE-REQUISITES:	Sound speed Sound intensity Frequency; wavelength Use of sound intensity meter Use of electrical testing equipment Waveforms: single frequency, music, noise	
MATERIALS: EQUIPMENT, APPARATUS:	Sound intensity meter Oscilloscope Microphone Industrial equipment (band saw, lathe, drill press, table saw, etc.)	
TIME FRAME:	One 50-minute period	
TEACHING STRATEGIES:	Use the Technology labs (for equipment). Mathematics teacher will cover logarithms. Physics teacher will cover sound intensity and frequency. Technology teacher will cover the use of the sound intensity meter and lab orientation with industrial equipment.	

TEACHING METHODOLOGY:

Review Physics and Math concepts in pre-lab

Lab orientation/demonstration

Lab activity

Student lab write-ups

Post-lab session

FURTHER FIELDS OF INVESTIGATION:

Measure sound intensity level at a professional sporting event.

Measure sound intensity level at an industrial plant and compare to OSHA standards.

Measure sound intensity level at an airport and compare to OSHA standards.

PROCEDURE: This activity will illustrate noise with respect to loudness. Industry has loudness codes to protect the worker from excessive noise pollution. The oscilloscope will be used to examine the difference between noise, music, and a single frequency. Sketches will be made of each waveform as seen on the oscilloscope. A sound intensity meter will be used to make loudness comparisons (in decibels) of various industrial equipment. The measurements will then be converted to intensity units (watts/cm^2). A scale from lowest intensity to highest intensity will be made to show the relationship of the loudness of equipment used in industrial factories.

Part I. Oscilloscope and Sound Waves

A. Connect a microphone to an oscilloscope. Turn on the scope. Set the Volts/Div. and Time/Div. such that when you speak into the microphone, a waveform will appear on the scope.

B. After placing the microphone close to a band saw, cut a piece of wood with the band saw.

C. Note the waveform on the oscilloscope. Sketch the waveform below.

Does the waveform represent a single frequency, music, or noise?________________________________

D. Place the microphone close to a drill press and drill into a piece of wood.

E. Note the waveform on the scope. Sketch the waveform below.

Does the waveform represent a single frequency, music, or noise?______________________________

F. Have a band student play a reed instrument letter C into the microphone.

G. Note the waveform on the scope. Sketch the waveform below.

Does the waveform represent a single frequency, music, or noise?

H. Have the band student play the letter C one octave higher than that played in part F.

I. Sketch the observed waveform below. Compare it to the waveform in part G.

Does the waveform represent a single frequency, music, or noise?

Part II. Sound Intensity Meter (loudness sensor)

Use the loudness meter to determine the decibel range of a band saw, drill press, lathe, table saw, sander, grinder, and planer or other machines.

Note: You may have to adjust the range on the meter according to the loudness of the equipment.

1. Record the decibel reading in Table G-5-1 ("Sound Intensity Readings").
2. Convert the decibel reading into watts/cm². Use the following equation to solve for I when $I_o = 1x10^{-16}$ watts/cm² (threshold of hearing).

$$\beta = 10 \log I/I_o$$

ANTICIPATED PROBLEMS:

Selecting the correct range with the sound intensity intensity meter.

Viewing the oscilloscope and sketching a fixed waveform.

METHODS OF EVALUATION:

Observation during the lab activity
Post-lab write-up
Selected quiz items on the Unit Test

FOLLOW-UP ACTIVITIES:

Go to various places in the community and take some decibel readings to determine levels of intensity.

Connect the sound intensity meter to an oscilloscope or frequency analyzer and observe the waveforms. Other musical instruments could be used to compare the waveforms and quality of sound. Beats could be observed on the oscilloscope. Higher octaves could also be observed on the oscilloscope.

REFERENCES, RESOURCES, VENDORS:

Radio Shack

Central Scientific Company
11222 Melrose Ave.
Franklin Park, IL 60131-1364

Science Kit & Bonreal Lab.
777 East Park Drive
Tonawanda, NY 14150-6784

Sargent-Welch
P.O. Box 1026
Skokie, IL 60076-1026
(800) 729-4368

Fisher Scientific-EMD
4901 W. LeMoyne Street
Chicago, IL 60651
(800) 621-4769

Scientic equipment vendors

Industrial testing equipment vendors

Realistic (Tandy Corporation)

Table G-5-1

Sound Intensity Readings

Equipment	Intensity (dB)	Intensity (watts/cm^2
band saw		
drill press		
lathe		
table saw		
sander		
grinder		
planer		

INDUSTRIAL SAFETY POST-LAB QUESTIONS

1. Make a decibel scale from lowest intensity to highest intensity using the reading in Table G-5-1 from the lab activity. (Use 0 dB as threshold of hearing and 140 dB as threshold of pain.)

2. Name three places where the sound intensity is beyond the threshold of pain.

3. Why is it important for companies to know the loudness of their equipment?

4. What is the difference between noise and music? (Answer in a complete sentence and also show a sketch of the differences.)

5. What is the intensity level in decibels of a shot gun that has an intensity of $1x10^{-7}$ watts/cm^2?

INDUSTRIAL SAFETY MATHEMATICS WORKSHEET

If the power input to a network or device is P_1 and the power output is P_2, the amount of decibels gained or lost in the device is given by the logarithmic equation:

$$G=10\log_{10}\frac{P_2}{P_1}\ dB$$

Solve the following problems:

1. A certain amplifier gives a power output of 1000 W for an input of 50 W. Find the dB gain.

2. A transmission line has a loss of 3.25 dB. Find the power transmitted for an input of 2750 kW.

3. What power input is needed to produce a 250 W output with an amplifier having a 50 dB gain?

4. The output of a certain device is half the input. This is a loss of how many decibels?

ACTIVITY 6: FIBER OPTICS

TECHNOLOGICAL FRAMEWORK:

Fiber optics is the beginning of a large area of technical change. For many years, we have used light simply to illuminate our living and working areas. Now we have started to use light to transmit information. What are the advantages of this over conventional electrical transmission? First, light is not affected by magnetic fields the way that electricity is. Second, messages sent by light may be multiplexed which allows many messages to be carried on the same conductor. Besides the telecommunications industry, light-operated devices are being developed in the computer field. Light-operated computers will be faster, less affected by line surges, cooler, and more efficient. Fiber optics is really just in its infancy. There are many things yet to come from this infant area of technology.

PURPOSE:

To demonstrate the use of fiber optics for carrying high frequency signals from a sine wave generator to an audio speaker.

To demonstrate how a wavelength changes with a change in frequency.

To demonstrate the lower and higher limits of audibility.

To make a comparison between a calculated and a measured wavelength for sound.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:	Physics: Frequency Wavelength Velocity of sound Amplitude	Mathematics: Graphing of functions
	Technology: Fiber optic communications	
PRE-REQUISITES:	Fiber optics Total internal reflection Index of refraction Use of electrical testing equipment	
MATERIAL, EQUIPMENT, APPARATUS:	Sine-wave generator Small transformer (to operate speaker) Oscilloscope Audio speaker (57mm) Fiber optic receiver module (ECI) Fiber optic supply (0-25 VDC) Plug-in module (circuit panel) Multimeter	
TIME FRAME:	Two 50-minute periods	
TEACHING STRATEGIES:	Group students by threes. Use the Physics or Electronics lab. Mathematics teacher will review graphing of functions (sine curve). Physics teacher will cover wave theory, index of refraction, total internal reflection, and fiber optics. Technology teacher will cover operation of electrical testing equipment and the lab orientation.	

TEACHING METHODOLOGY:	Review the Mathematics and Physics pre-requisites Lab demonstration of the electrical testing equipment Lab activity Post-lab session and write-up
FURTHER FIELDS OF INVESTIGATION:	Telephone communication systems (optical communication) Orthoscopic surgery Light pipes

PROCEDURE: A fiber optic circuit will be connected to a sine/square wave generator, oscilloscope, multimeter, and speaker. It will be possible to conceptualize how electrical energy is converted to light energy, then back to electrical energy, and finally to sound energy. The fiber optic cable acts as a carrier of the high frequency light (4.3×10^{14} Hz - 7.5×10^{14} Hz) and is decoded in the audio range (20 Hz - 20,000 Hz) at the receiving end. Most fiber optic communication systems use digital modulation to carry information with encoding and decoding at the two ends. It will be possible to calculate the speed of sound in the classroom/lab and use this information to determine the sound wavelength. The wavelength will also be measured with the use of the oscilloscope and then compared to the calculated wavelength.

Part I. Audio Spectrum

A. Each module, the fiber optic transmitter and the receiver, has a dual operation amplifier (op amp). This is the Bias and Gain as shown in Figure G-6-1 ("Gain/Bias Location"). The op amp is used to improve the amplification and clarity of an audio signal or to improve the sine wave produced by an oscilloscope.

B. Insert the fiber optic transmitter module into the bread board. Turn both the Bias and Gain to the maximum clockwise position.

C. Connect the leads as shown in Figure G-6-2 ("Fiber Optic Transmitter Wiring Diagram"). Be sure the power supply is set at 12 VDC with a multimeter.

D. Turn on the power supply, sine wave generator, and oscilloscope at this time. On the oscilloscope, set channel one time base to 1 ms/div and channel one voltage to 2 volts/div. Turn the Bias control counterclockwise to about the 1/2 position or until the sine wave is undistorted. It may still be clipped. If the sine wave is clipped on both the top and bottom, try reducing the generator output level. If only the top or only the bottom is clipped, adjust the Bias control. The sine wave will most likely be a chopped sine wave.

E. Turn off the components.

F. Plug a fiber optic receiver module into the bread board. Connect the fiber optic circuits as shown in Figure G-6-3 ("Fiber Optic Component Wiring Configuration"). Set the Bias and Gain controls on the receiver to their minimum positions (maximum counterclockwise position).

G. Turn on the components. Adjust the Bias and Gain controls on the fiber optic receiver module for best results on the oscilloscope. The sine wave may be clipped.

H. Set the oscilloscope with channel one time base to 1 ms/div and channel one voltage to 2 volts/div.

The next two steps are to be done for each member in your group.

I. Set the frequency to 10 Hz. Gradually increase the frequency until an audio signal is heard from the speaker.

Record the frequency when the signal is heard.

lower limit
of audibility = __________Hz

Note: If the frequency is not heard by 1000 Hz, check all connections as per the diagram in Figure G-6-3.

J. After recording the lower limit of audibility, continue to increase the frequency until you no longer hear a signal from the speaker. Record the frequency.

upper limit
of audibility = __________Hz

(In steps I and J, it may be necessary to take several readings and then average them.)

Part II. Frequency and Wavelengths

A. Given the room temperature in Fahrenheit degrees, convert to Celsius degrees.

$$^{\circ}C = (5/9)(^{\circ}F - 32)$$

B. The speed of sound at $0^{\circ}C = 331.5$ m/s and increases as the temperature increases (approximately 0.6 m/s per C°).

Determine the speed of sound in the lab.

speed of sound = __________m/s

C. Calculate wavelength of sound for the five different frequencies in Table G-6-1, "Wavelength--Calculated/Measures." Record the calculated λ in Table G-6-1.

$$\lambda = \frac{V_{sound}}{f}$$

D. Using the connections shown in Figure G-6-3, set the frequency of the signal generator and the Time/Div on the oscilloscope as indicated in the first row of Table G-6-1. Record the measured wavelength on the oscilloscope. This can be done by counting the number of time divisions and then multiplying by the Time/Div. Next, multiply the result by the speed of sound in the lab. (Refer to step B.)

$$\lambda = V\,T$$

Record the measured λ in Table G-6-1.

E. Repeat step D for the remaining four values of frequency and Time/Div values.

METHOD OF EVALUATION:

Observation during the lab

Post-lab write-up

Selected quiz items on the Unit Test

FOLLOW-UP ACTIVITIES:

Telephone companies use fiber optic cables as transmission lines for telephone conversations. Multiplexing is a method used for allowing several thousand conversations to travel through the same line at the same time. It would be beneficial to have a guest speaker from a telephone company make a presentation to further enhance this topic. Fiber optics are also used in medical applications such as for a light pipe. A guest speaker on medical technology could elaborate further on this topic. Students could do a library report on additional uses of fiber optics.

REFERENCES, RESOURCES, VENDORS:

Energy Concepts, Inc.
7440 No. Long Ave.
Skokie, IL 60077
(708) 283-4422

Aidex Corporation
1802 N. Division St.
Morris, IL 60450
(800) 251-9935

Scientific equipment vendors

Central Scientific Company
11222 Melrose Ave.
Franklin Park, IL 60131-1364

Science Kit & Bonreal Labr.
777 East Park Drive
Tonawanda, NY 14150-6784

Sargent-Welch
P.O. Box 1026
Skokie, IL 60076-1026
(800) 729-4368

Fisher Scientific-EMD
4901 W. LeMoyne Street
Chicago, IL 60651
(800) 621-4769

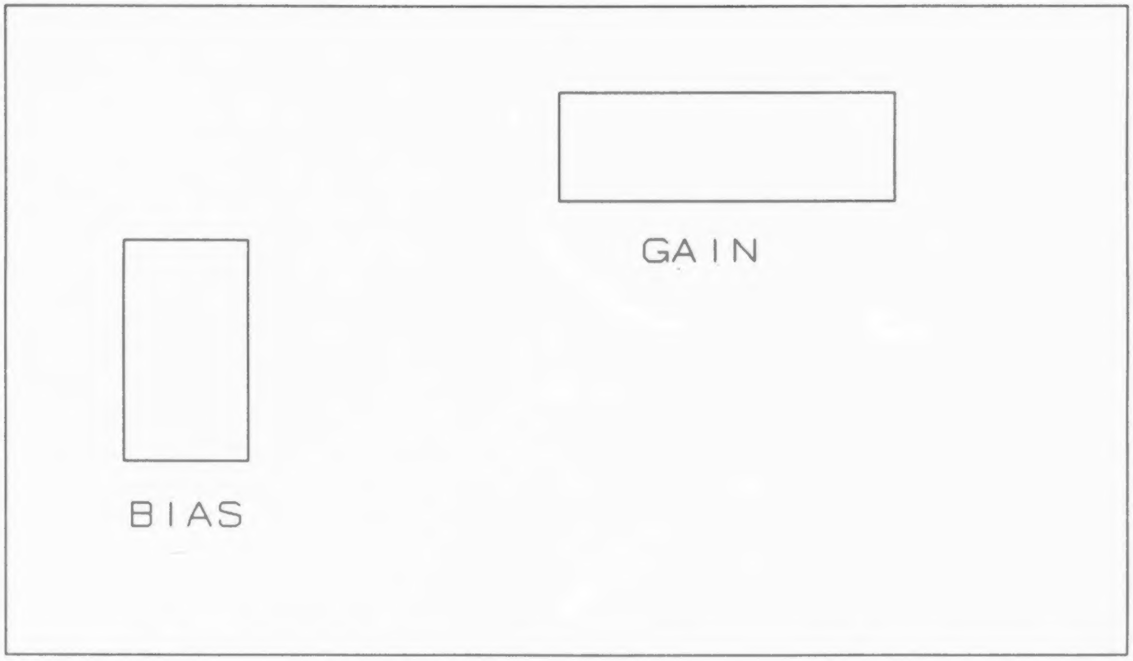


Figure G-6-1

Gain/Bias Location

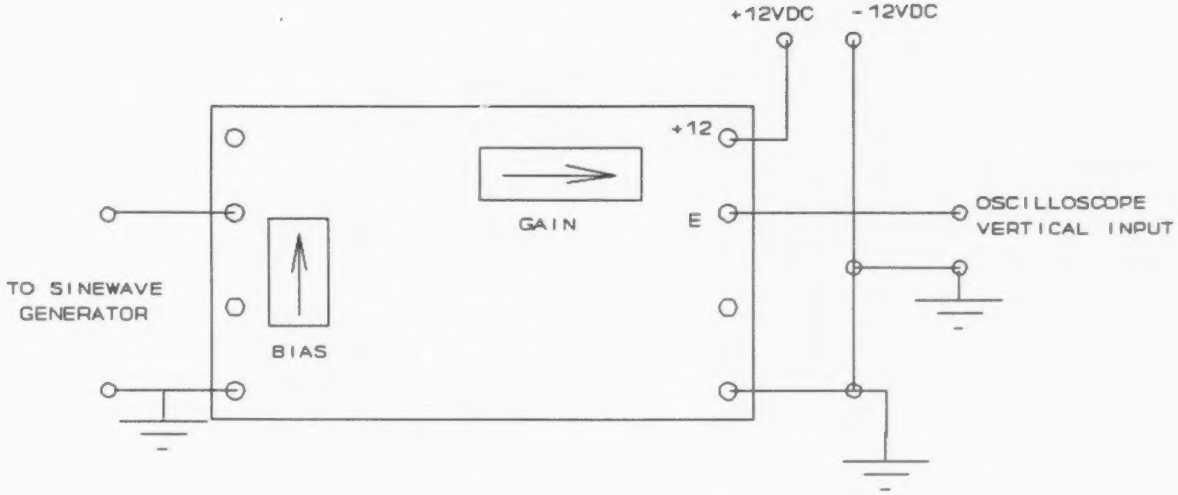

+12VDC
-12VDC
+12
GAIN
E
OSCILLOSCOPE
VERTICAL INPUT
TO SINEWAVE
GENERATOR
BIAS

Figure G-6-2

Fiber Optic Transmitter Wiring Diagram

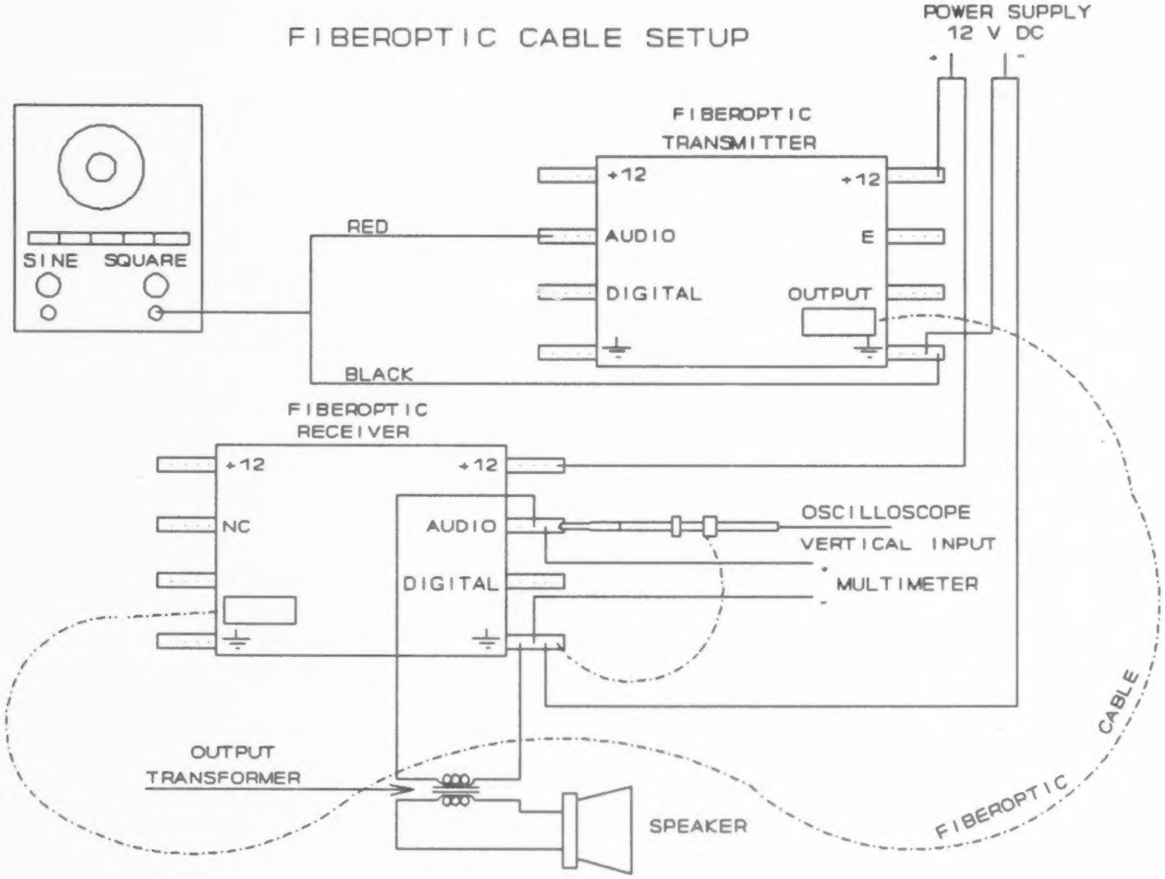

FIBEROPTIC CABLE SETUP
POWER SUPPLY 12 V DC
+
-
FIBEROPTIC TRANSMITTER
+12
+12
AUDIO
E
DIGITAL
OUTPUT
RED
BLACK
SINE
SQUARE
FIBEROPTIC RECEIVER
+12
+12
NC
AUDIO
DIGITAL
OSCILLOSCOPE
VERTICAL INPUT
+
MULTIMETER
-
OUTPUT TRANSFORMER
SPEAKER
FIBEROPTIC CABLE

Figure G-6-3

Fiber Optic Component Wiring Configuration

Table G-6-1

Wavelength--Calculated/Measured

Frequency	Time/Div.	Calculated λ	Measured λ
60 Hz	5 mS		
100 Hz	2 mS		
500 Hz	1 mS		
7000 Hz	.1 mS		
15000 Hz	5 S		

FIBER OPTICS POST-LAB QUESTIONS

1. Calculate the wavelength of your lower and upper limits of audibility.

2. How do these limits compare to the wavelength calculated in Part II of the lab activity?

3. What happened to the wavelength as the frequency was increased?

4. What is the total internal reflection?

5. The echo of a car horn reflects from a mountain and is heard 3 seconds after the car horn is sounded. The temperature is 25°C. How many meters away is the mountain?

6. As a train comes toward you, it has a higher frequency pitch. As the train passes you, it has a lower frequency pitch. In terms of wavelength, explain this phenomenon.

7. In the lab activity completed, how does the measured value compare to the calculated value?

8. On a separate sheet of graph paper, graph the wavelength as a function of the frequency (frequency on the horizontal).

9. Explain the energy conversion system used in the activity. (Hint: Trace the path of energy from the sine wave generator to the speaker.)

FIBER OPTICS MATHEMATICS WORKSHEET

1. Converting Fahrenheit degrees to Celsius degrees:

$$^{\circ}C = \frac{5}{9}\ (^{\circ}F - 32^{\circ})$$

a. $32^{\circ}F = \ ?\ ^{\circ}C$

b. $72^{\circ}F = \ ?\ ^{\circ}C$

c. $0^{\circ}F = \ ?\ ^{\circ}C$

d. $50^{\circ}F = \ ?\ ^{\circ}C$

Express °C to the nearest whole degree.

2. Converting Celsius degrees to Fahrenheit degrees:

$$^{\circ}F = \frac{9}{5}\ ^{\circ}C + 32^{\circ}$$

a. $0^{\circ}C = \ ?\ ^{\circ}F$

b. $100^{\circ}C = \ ?\ ^{\circ}F$

c. $50^{\circ}C = \ ?\ ^{\circ}F$

d. $20^{\circ}C = \ ?\ ^{\circ}F$

Express °F to the nearest whole degree.

ACTIVITY 7: DEVELOPMENT OF A SOLAR-POWERED TRANSPORTER

TECHNOLOGICAL FRAMEWORK:

Energy efficiency, doing more with less, is a very important topic in our world today. Solar power is one of the alternative energy sources available to us now and in the foreseeable future. There can be no doubt that we must convert our energy use from non-renewable sources to renewable sources. How soon we must do this depends on how efficient our current energy systems are. Much research is presently being done in the field of solar energy. Much more will have to be done in the future. In order to continue research, we need creative, team-oriented people. By using the team problem-solving approach in this lab, we will be fostering not only creative thinking but also teamwork in a realistic work setting. This should better enable our students to be more valuable, productive members of society.

PURPOSE:

To demonstrate the power output of a solar array by powering a model vehicle.

To better develop the team approach to problem solving.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
Speed
Acceleration
Work
Power
Force

Technology:
Solar cells
Motors
Mechanical systems
Mechanical design

Mathematics:
Evaluation of formulas
Calculator applications
Transformation of equations

PRE-REQUISITES:

Using meters to measure voltage and current
Photoelectric effect
Understanding motion and energy
Photovoltaic cells
Mechanics
Electron hole generation in semiconductor solar cells

MATERIALS, EQUIPMENT, APPARATUS:

Solar array, motor, card stock, drive train, motion detectors, photocell timers, glue, spring scale, voltmeter, ammeter, power supply, metric tape, eggs, computer with Ultra Sound software, Superchamp.

Other materials will be necessary, depending on the various team designs. Cost should be kept to a minimum when considering additional materials.

TIME FRAME:

Five 50-minute periods

TEACHING STRATEGIES:

Group class by threes or fours.

Physics teacher will conduct review of physics concepts.

Technology teacher will conduct the lab activity.

Mathematics teacher will assist the other two teachers as they work with the groups on their problem-solving skills.

Team problem solving is a strategy which involves the teacher as a facilitator rather than an information giver. Unless students are familiar with this process, things will go very slowly at first. It is important that the process be allowed to run its course. If the teacher gives too much help, the students will not think on their own. Let the students be creative.

Any design may work well. Students may use wheels, tracks, legs, wings, or any number of other means. The real benefit of this activity may be in the post-lab activity when physics concepts can be used to explain why one design worked better than another.

TEACHING METHODOLOGY:

Pre-lab session for review of physics concepts and problem solving as a team concept
Lab orientation
Lab activity
Lab write-ups
Vehicle testing
Post-lab problem solving

FURTHER FIELDS OF INVESTIGATION:

The GM SUNRAYCER

Using solar energy to reduce our use of non-renewable energy sources

Industrial problem solving

Non-destructive vehicle testing

Solar-powered calculators

PROCEDURE: This activity involves the TEAM concept. The TEAM will build a solar-powered transporter using card stock, solar array, and motor. Measurements will be taken of the voltage and current for both the solar array and motor. The TEAM's objective will be to transport a fresh egg over a 5-meter distance. The TEAM will determine the vehicle's speed, acceleration, work, and power.

Part I. Motor and Solar Array Specifications

A. With the power off, measure the load resistance of the motor. Record the resistance in Table G-7-1, "Solar Array/Motor Table."

B. With the motor attached to the solar cell, measure the voltage produced. Record the voltage in Table G-7-1.

C. Calculate the power produced by the cell using:

$$P = V^2/R$$

Record the calculation in Table G-7-1.

Part II. Stating the Problem

Using your solar array, motor, and card stock, design a vehicle which will transport an egg 5 meters in distance.

The vehicle must be constructed from card stock. Other materials can be used to complete the drive train.

Part III. The Development of a Vehicle

A. Each team is to study the problem and do some brainstorming (as a team) to come up with a possible solution.

B. The team will discuss their possible solution and arrive at a plan of action.

C. The team will then make a list of necessary components to complete the drive train.

D. After obtaining the material for the drive train, the team will construct the vehicle.

Part IV. Testing of the Vehicle

A. Have the vehicle run the required 5-meter distance. (Refer to Table G-7-2, "Acceleration and Power," for recording of data from parts A-F).

   1. Use a photo cell timing device to record the total elapsed time (seconds).

   2. Use a motion detector at the finish line to determine the final speed (m/s). (The motion detector will detect the speed of an object that passes by its beam.)

B. Calculate the average speed of the vehicle.

$$V_{ave} = d/t; \text{ (m/s)}$$

C. Calculate the acceleration of the vehicle.

$$a = (V_f - V_o)/t; \text{ (m/s}^2\text{)}$$

D. Measure the mass of the vehicle and its load in newtons using a spring scale. (Pull the transporter parallel to the ground at a constant speed.)

E. Calculate the work done by the vehicle.

$$W = Fd; \text{ (joules)}$$

F. Calculate the power of the vehicle.

$$P = W/t; \text{ (watts)}$$

G. Calculate the distance traveled by the vehicle using this equation:

$$d = V_o t + 0.5at^2.$$

Record this distance in Table G-7-2. Determine the absolute error and the relative error and record in Table G-7-3, "Error Analysis."

ANTICIPATED PROBLEMS:	Is the solar array large enough to power the motor for the vehicle? Is the weight of the entire vehicle too much?
METHODS OF EVALUATION:	Observation during the problem-solving and construction phases in the activity Vehicle testing results Post-lab write-up Post-lab problem solving
FOLLOW-UP ACTIVITIES:	View a video tape on the World Solar Challenge Races (GM Sunraycer). Hold a class discussion on energy conservation and the environment. It may be possible to construct a solar cell from a purchased kit. Have the students record all of their data in a class master chart (refer to Tables G-7-1, G-7-2, and G-7-3) for further class discussion. Have them compare the different speeds, accelerations, forces, work, and power of each of the constructed transporters.

REFERENCES,
RESOURCES,
VENDORS:

Central Scientific Company
11222 Melrose Ave.
Franklin Park, IL 60131-1364

Science Kit & Bonreal Labr.
777 East Park Drive
Tonawanda, NY 14150-6784

Sargent-Welch
P.O. Box 1026
Skokie, IL 60076-1026
(800) 729-4368

Fisher Scientific-EMD
4901 W. LeMoyne Street
Chicago, IL 60651
(800) 621-4769

Science vendors

Novan solar appliances

Solar Today magazine
Publisher:
American Solar Energy Society
Boulder, CO 80301

Los Alamos Sales Company
P.O. Box 795
Los Alamos, NM 87544
(505) 662-5053

Table G-7-1

Solar Array/Motor Table

Measured Distance (m)	Calculated Distance (m)	Absolute Error (m)	Relative Error (%)

Table G-7-2

Acceleration and Power

Distance	Time	Final Speed	Ave. Speed	Accel-eration	Force (N)	Work	Power

Table G-7-3

Error Analysis

Measured Distance (m)	Calculated Distance (m)	Absolute Error (m)	Relative Error (%)

SOLAR-POWERED TRANSPORTER POST-LAB QUESTIONS

1. Compare the power output of the solar array to the power output of the vehicle to determine its efficiency.

2. After testing your vehicle, what changes would you recommend in the construction to make the vehicle operate more efficiently?

3. A turbo golf cart accelerates from 5 mph to 15 mph in 3 seconds. What is the acceleration of the golf cart in m/s^2?

4. A driver of a Porche 911 sees a deer standing in the middle of the road. The driver hits the brakes hard to avoid the deer. The car decelerates at $5.5\ m/s^2$.

   a. What time is required to reduce the speed of the car from 60 km/h to 15 km/h?

   b. How many meters has the car traveled during the deceleration?

5. How much horsepower did your solar array develop?

6. Attach a critique of the other teams' vehicles with suggestions for improvement.

7. Why does the transporter work outside under sunlight but not inside under fluorescent light?

MATHEMATICS WORKSHEET

Solve:

1. When a body moves with constant acceleration a (such as in free fall), its velocity V at time t is given by

$$V = V_o + at,$$

where V_o is the initial velocity. Note that this is the equation of a straight line. If a body has a constant acceleration of 2.15 m/s^2, and has a velocity of 21.8 m/s at 5.25 s, find (a) the initial velocity, and (b) the velocity at 25.0 s.

2. A boat sails 30 km at a uniform rate. If the rate had been 1 km/h more, the time of the sailing would have been 1 h less. Find the rate of travel.

3. An object is thrown upward with a velocity of 145 ft/s. When will it be 85 ft. above its initial position?

(Use $d = V_o t + \frac{1}{2}gt^2$)

4. The formula for the displacement d of a free falling body having an initial velocity V_o and acceleration a is

$$d = V_o t + \frac{1}{2} g t^2$$

Solve this equation for g.

ACTIVITY 8: HALL EFFECT

TECHNOLOGICAL FRAMEWORK: Since the Hall Effect can demonstrate a potential difference in a conductor in a magnetic field, it can be used to determine the strength of the magnetic field by measuring the perpendicular Hall voltage. This is beneficial to industries use electromagnets. It is important to be able to determine the size of the magnetic field and its direction, both when carrying a load and knowing when to release the load.

PURPOSE: To demonstrate the digital Hall sensor performance as a load switch and the linear Hall sensor as a voltage variance due to magnetic fields.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
Voltage
Magnetic flux
Magnetic fields
Force
Strain

Mathematics:
Graphing of functions

Technology:
Hall Effect Keypads
Weight sensing devices
Drop switches for cranes

PRE-REQUISITES:
Magnetic flux
Magnetic fields
DC fundamentals
Force

MATERIALS, EQUIPMENT, APPARATUS:
Power supply
Digital multimeter
Hall Effect module (ECI)
Masses
Plug-in module (circuit panel)

TIME FRAME:
One 50-minute period

TEACHING STRATEGIES:

Group students by threes.

Use the Physics/Electricity lab.

Mathematics teacher will review graphing of functions and scaling.

Physics teacher will cover magnetic flux and magnetic fields.

Technology teacher will cover strain gauges, operation of electrical testing equipment, and the lab orientation.

TEACHING METHODOLOGY:

Review physics and math pre-requisites

Review use of testing equipment

Lab activity

Post-lab session and write-up

FURTHER FIELDS OF INVESTIGATION:

Mechanical strain gauges (pressure sensor)

Electrical switch on typewriter keyboard

Load switch

PROCEDURE:

The Hall Effect, discovered in 1879, is the development of a potential difference on opposite surfaces of a conductor which is in a magnetic field. The polarity of the Hall Effect EMF in conductors (metals) may be opposite to that of semiconductors. This is helpful in determining whether the charge carriers are negative (electrons) or positive (holes). The Hall Effect module has two built-in sensors. One sensor is a switching device for voltage (Digital) and the other sensor has a proportional change of voltage with respect to the strength of the magnetic field (Linear). The polarity of the Hall voltage is dependent on the direction of the magnetic flux. A force applied to the magnet causes a magnetic field disturbance and the voltage will change. Voltage will be taken with the Hall Effect in different positions for both sensors. Hysteresis will be examined, which is a damping or slowing down of the voltage caused by the magnetic field.

Part I. Digital Hall Sensor

A. Set the DC power supply at 12 VDC output. Connect + lead 12 VDC to +12 point on the Digital Effect sensor. Connect -12 VDC to ground. Connect the multimeter. (Refer to Figure G-8-1, "Digital Hall Sensor Wiring Diagram.")

B. On the Digital Hall sensor, be sure to have the magnet position such that the red dot end is to the left. (Refer to Figure G-8-2, "Hall Effect Magnet Position Diagram.")

C. Turn on the power supply and the multimeter. Record the voltage as viewed on the multimeter when the magnet has no force applied to it (up position).

V = ___________

D. Apply a force (your finger) to the magnet, pushing it down toward the base of the module. View the voltage on the meter as the magnet gets closer to the base. When the magnet is at its lowest position, record the voltage.

V = ___________

E. Slowly allow the magnet to return to its up position. View the voltage on the meter as the magnet returns to the up position. Record the voltage when the magnet is back to the up position.

V = __________

F. Repeat steps C-E and note if there is a lag between the increasing and decreasing values of voltage. This is called **Hysteresis**. Record your findings.___________________________________
____
____

Part II. Linear Hall Sensor

A. Set up the circuit and multimeter as shown in Figure G-8-3 ("Linear Hall Sensor Wiring Diagram"). Have the magnet in the neutral position (vertical).

B. Turn on the power supply and the meter. Record the voltage as viewed on the meter.

V = __________

C. With your finger, rotate the magnet 360°. During the rotation, view the voltage on the meter (do not push down on the magnet). Record your results.___________________________________
____
____

D. With the magnet in the neutral position, apply a mass of 50 g to the magnet. Record the voltage in Table G-8-1 ("Hall Effect--Force/Voltage Table"). Repeat this for the other four masses listed.

ANTICIPATED PROBLEMS:	Check for proper meter connections and ranges. (The transistors are sensitive devices and cannot handle backwards voltage.) Applying the masses to the magnet of the Hall Effect module may require some creative planning. (You need to use non-magnetic masses.)
METHODS OF EVALUATION:	Observation during the lab activity Post-lab write-up and graphs Selected quiz items on the Unit Test
FOLLOW-UP ACTIVITIES:	An old typewriter keyboard can be examined to study the touch sensor pads which use the Hall Effect. A field trip to an industry where the Hall Effect is used in the form of strain gauges can enhance this unit. A class discussion can then follow on why strain gauges such as force or pressure are important.
REFERENCES, RESOURCES, VENDORS:	Energy Concepts, Inc. 7440 No. Long Avenue Skokie, IL 60077 (708) 283-4422 Aidex Corporation 1802 N. Division St. Morris, IL 60450 (800) 251-9935 Radio Shack (a division of Tandy Corporation)

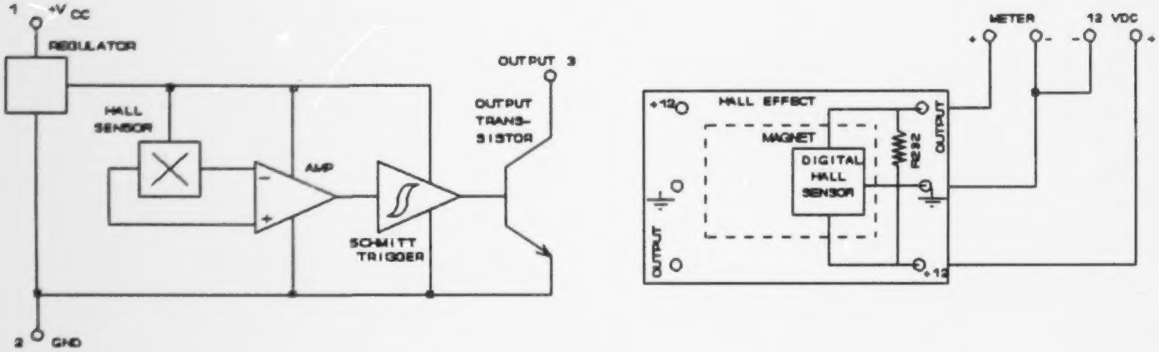

1
+V CC
REGULATOR
HALL SENSOR
AMP
SCHMITT TRIGGER
OUTPUT TRANS-SISTOR
OUTPUT 3
2
GND
METER
12 VDC
+
-
-
+
+12
HALL EFFECT
MAGNET
DIGITAL HALL SENSOR
R232
OUTPUT
OUTPUT
+12

Figure G-8-1

Digital Hall Sensor Wiring Diagram

Figure courtesy of Energy Concepts Inc.

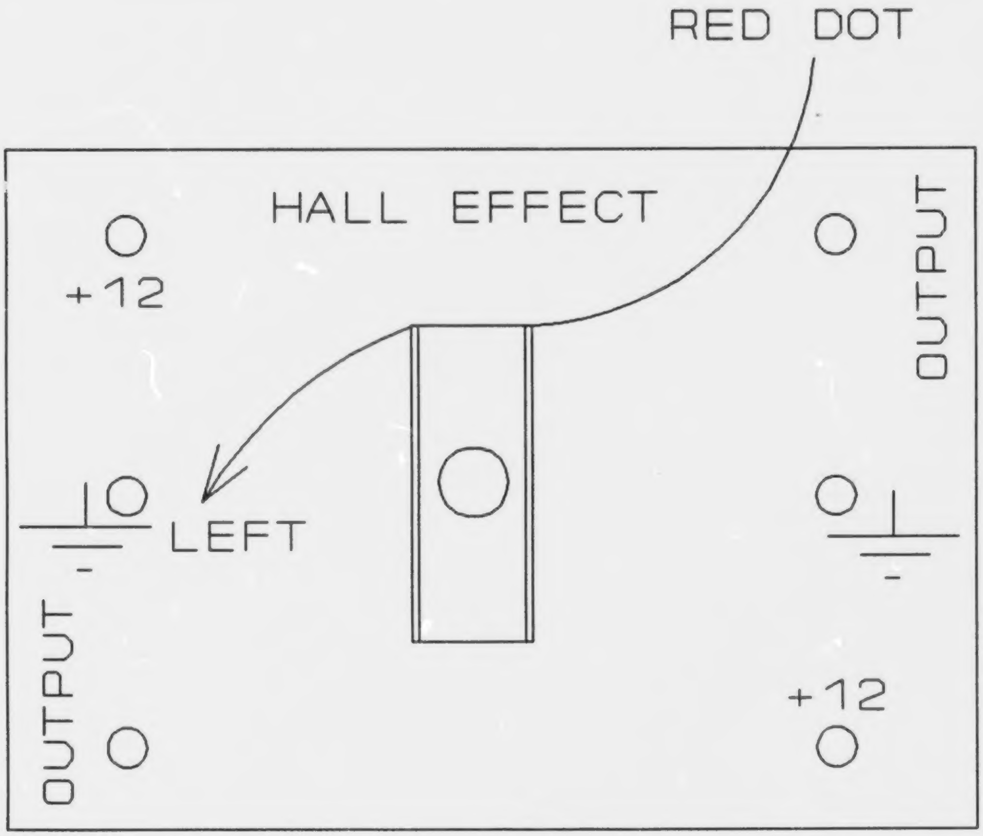

RED DOT
HALL EFFECT
+12
OUTPUT
LEFT
-
OUTPUT
-
+12

Figure G-8-2

Hall Effect Magnet Position Diagram

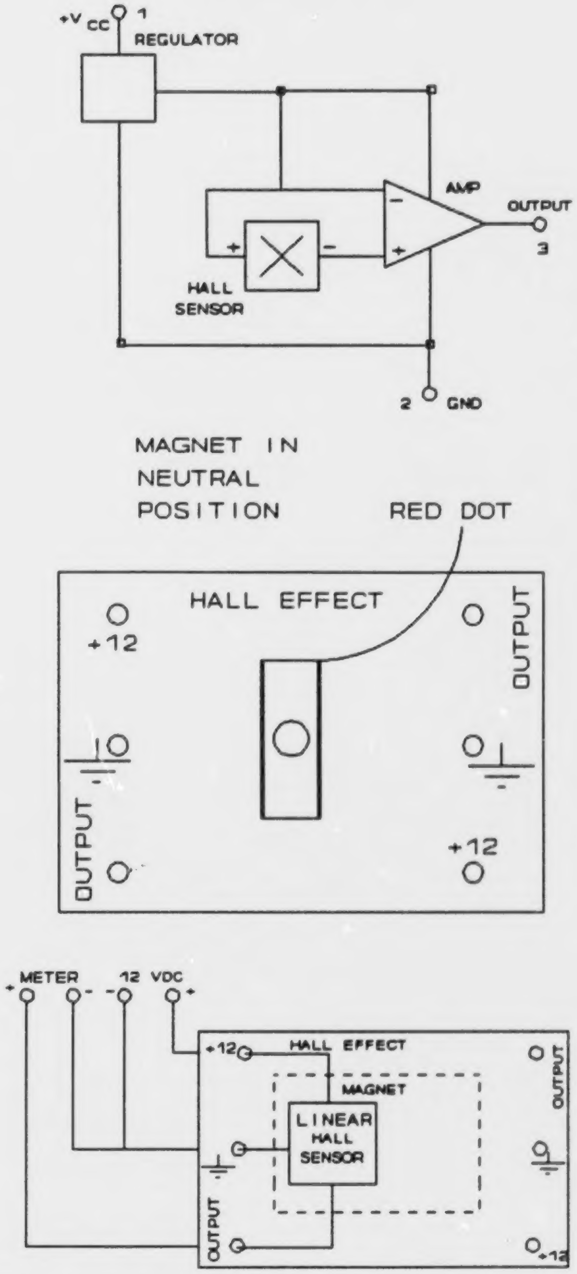

+V CC
1
REGULATOR
AMP
OUTPUT
3
HALL
SENSOR
2
GND
MAGNET IN NEUTRAL POSITION
RED DOT
HALL EFFECT
+12
OUTPUT
OUTPUT
+12
METER
12 VDC
+12
HALL EFFECT
MAGNET
LINEAR HALL SENSOR
OUTPUT
OUTPUT
+12

Figure G-8-3

Linear Hall Sensor Wiring Diagram

Table G-8-1

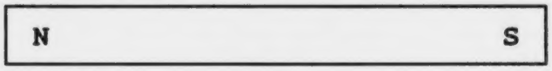
Hall Effect-Force/Voltage Table

Mass	Force	Voltage
50 grams		
150 grams		
250 grams		
350 grams		
450 grams		

HALL EFFECT POST-LAB QUESTIONS

1. On a sheet of graph paper, graph the voltage as a function of force. Use Figure G-8-1 from Part II of the lab activity.

2. Sketch the magnetic flux lines about a bar magnet.

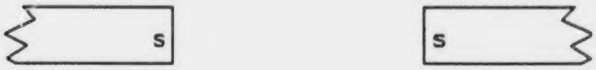


3. Compare the Linear Hall sensor voltage to the Digital Hall sensor voltage. State your findings.

4. Although both sensors use the same basic concept, how might each be used?

5. Sketch the magnetic flux lines between the two N poles.

6. Sketch the magnetic flux lines between the two S poles.



Supplement on the TI-81 Calculator

For two-variable data, the STAT CALC menu has four regression models for curve fitting and forecasting. The X value is interpreted as the independent variable and the Y value as the dependent variable.

To enter DATA in pairs, you use **2nd Matrix** and use the right arrow to select **DATA**. You want to use **1:Edit**, so just use the **Enter** key. Next, you enter the DATA in pairs for x1, y1, etc.

To clear the screen, the you use **2nd Clear**. Now use **2nd Matrix** again and select Draw. Choose **2:Scatter** followed by **Enter**. You will see a scattering of your points. To clear a drawing, you use **2nd PRGM** and select **1:ClrDraw** and **Enter**.

To calculate the results of your data, press **2nd Matrix** to display the STAT CALC menu. Choose the type of regression model you think might fit the scatter plot you saw earlier. To calculate a linear regression mode, select **2:LinReg**. To calculate a logarithmic regression model, select **3:LnReg**. To calculate an exponential regression, select **4:ExpReg**. To calculate a power regression model, select **5:PwrReg**.

Model	Formula	Restrictions
Linear	$Y = a + bX$	
Logarithmic	$Y = a + b\ln(x)$	All X values > zero
Exponential	$Y = ab^x$	All Y values > zero
Power	$Y = aX^b$	All X and Y > zero

The TI-81 calculates the values for a and b according to the selected regression model. In addition, the TI-81 calculates r, the correlation coefficient, which measures the goodness of the fit of the equation with the data. In general, the closer r is to 1 or -1, the better the fit; the closer r is to zero, the worse the fit.

<u>Sample</u> to try out ...

```
2nd Matrix Data <enter>
     3, 15, 4, 19, 2, 11, 5, 26, 6, 28
2nd Clear
2nd Matrix Draw 2: <enter>
((Study the scatter plot closely))
Clear Clear
2nd Matrix 2:<enter>          ****record the a, b, and r values
((repeat for 3:, 4:, and 5:))
```

Which one best fits the scatter plot?

What would be your estimate for X = 10?

HALL EFFECT MATHEMATICS WORKSHEET

Problem 1:

Read the supplement on the TI-81 graphics calculator and complete the sample given in that supplement.

(a) Sketch what the scatterplot looks like on the TI-81 screen.

(b) Go through each of the four possible selections and record the a, b, and r values.

(c) Indicate which regression best fits your scatter plot.

Selection:	Equation (a,b values):	Correlation Coefficient:
2: Lin Reg.	$y = a + b\,x$: $y =$	$r =$
3: Ln Reg.	$y = a + b \ln(x)$: $y =$	$r =$
4: Exp Reg.	$y = ab^x$: $y =$	$r =$
5: Pwr Reg.	$y = ax^b$: $y =$	$r =$

Problem 2:

Give a scatter plot of the date recorded in Part II of the Hall Effect activity (Voltage vs. Force).

Selection:	Equation (a,b values):	Correlation Coefficient:
2: Lin Reg.	$y = a + b\,x$: $y =$	$r =$
3: Ln Reg.	$y = a + b \ln(x)$: $y =$	$r =$
4: Exp Reg.	$y = ab^x$: $y =$	$r =$
5: Pwr Reg.	$y = ax^b$: $y =$	$r =$

ACTIVITY 9: REFLECTION HOLOGRAPHY: STRESS TEST OF MATERIALS

TECHNOLOGICAL FRAMEWORK:

Holography has successfully been used in several applications. These include credit cards, bank note identification, art, advertising displays, UPC codes, and interferometry (stress holography). Studying surface characteristics such as surface quality includes not only micro-roughness but also topography of the microstructure and detection of defects in materials. One way this area may be applied is with the use of interferometry or stress holography. Optical technicians study integrated circuits (ICs) for defects by looking at stress lines in holograms. Medical technicians can take holograms of bones and find areas of stress. Engineers at tire manufacturing plants use stress holography to look for defects in rubber tires. Stress holography and the use of holograms are having, and will continue to have, a powerful effect on our lifestyles.

PURPOSE:

To show how a holographic template can be used

To show stress lines in materials

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
Light (electromagnetic waves)
Interference pattern (Young's Double Slit experiment)
Stress/Strain (Young's Modulus)

Mathematics:
Exponential functions
Logarithmic functions

Technology:
Lasers
Holographic images
Holographic IQ's

PRE-REQUISITES:

Lasers

Interference pattern (Young's Double Slit experiment)

Electromagnetic waves

MATERIALS, EQUIPMENT, APPARATUS:

Helium-neon laser with 1-5 mW output
Small concave mirror or small convex lens
Thick black cardboard for shutter
Steel plate (1/4 x 12 x 12)
Squeegee (or wiper blade)
Magnets for attaching objects to steel plate
Hair blower for drying hologram
Green night light
Three glass trays for developing hologram
Holographic template or holographic film
Two large spring clamps
Small rubber inner tube
Rubber gloves for developing hologram
White light source for viewing hologram
Two 100-500 ml beakers for mixing chemicals
Small masses

TIME FRAME: Two 50-minute periods

TEACHING STRATEGIES:	Use the Technology lab. Physics teacher will cover holographic theory and laser technology concepts. Technology teacher will conduct the lab activity. Mathematics teacher will assist in the lab activity.
TEACHING METHODOLOGY:	Pre-lab session in the Physics lab Lab orientation Lab activity in Technology lab Lab write-up Viewing of stress patterns in holograms
FURTHER FIELDS OF INVESTIGATION:	Used in storing large bits of information Used in industry for fabrication of materials Used in Universal Product Code (UPC) Used for projecting information on a windshield in a car or airplane Used in testing for stress lines in tires Used in 3-dimensional movies (Holovision) Used in various forms of art

PROCEDURE:

Holography is a recording of interference patterns on a photographic template. In the 1800s, Thomas Young demonstrated interference of light by cutting two narrow slits 1 mm apart on black paper. When a light source was turned on 2-3 meters away, passing through a slit, a series of narrow bands (alternately dark and light) were seen. (Refer to Figure G-9-1, "Young's Double Split Interference Pattern.")

Young also noted that one interfering wave will undergo a phase inversion upon reflection. This is how waves interfere in reflection holograms.

Part I. The Set-up for Holography

A. Set up the apparatus as shown in Figure G-9-2 ("Holography Component Position Diagram"). Use magnets to hold down the spring clamps for supporting the holographic template.

B. Turn on the laser and position it such that the beam reflects off the concave mirror to illuminate the object fully.

C. Once you have the laser positioned properly, block off the beam with the shutter (thick card-board box top). (Refer to Figure G-9-3, "Holography Shutter Position Diagram.")

D. Turn on the green night light and turn off all other light sources before taking a holographic template out of the storage box or envelope. Be sure to hold the template carefully by the edges. Attach the template to the spring clamps you positioned in steps A-C. Be sure the emulsion (sticky) side is toward the object and away from the concave mirror.

E. Place a small mass on the object. Leave the entire set-up alone at this time for about 1-2 minutes to eliminate any motion from disturbing the development of the hologram. (Each group is to use a different sized mass on the object.)

Part II. Exposure of the Holographic Template

The exposure time is dependent on the wattage of the laser. (Example: A 1 mW laser should expose the template up to 20 seconds, while a 4 mW laser should be exposed for 2.5 seconds.)

Use the formula:

$$t = 40(0.5)^n$$

where n is the number of mW.

Caution: During the exposure time, movement must be non-existent.

A. Lift the shutter (carefully) for the required time limit. (A 4 mW laser would be for 2.5 seconds.)

B. Replace the shutter. Remove the mass (carefully) from the object and then wait 1-2 minutes.

C. Lift the shutter and allow for the required time limit from step A.

D. Replace the shutter. Remove the template from the spring clamps.

Part III. Development of the Hologram

The development process varies depending on the chemicals used. It is recommended you get the JD-2 Kit from The Photographer Formulary, Inc. or Integraf. Follow very carefully the directions that come with the kit as you mix the chemicals in the three glass trays. The directions in the kit give a step-by-step approach to the actual development of the hologram.

Part IV. Viewing the Stress Hologram

The hologram should be ready for viewing after completing all of the directions in the development process.

A. Use a point-source of light (the sun, overhead projector, etc.) and place the hologram into the path of light.

B. You should be able to view the object in the template. Look for bands of light and dark lines beneath where the mass was placed on the object. These lines represent lines of stress in the object.

C. How does the distance between the lines differ as your eyes move away from the mass?____________

____

____

____

ANTICIPATED PROBLEMS:

Exposure time may be inadequate.

There may be unnecessary movement in the lab.

There may be outside light interference.

Chemicals are dangerous and may last for only eight hours once mixed in the trays.

The mass added to the object may be too much and cause the hologram to become blurred or smear out of focus.

METHODS OF EVALUATION:

Observation during lab

Post-lab write-up

Selected quiz items on a Unit Test

FOLLOW-UP ACTIVITIES:

Instead of using a mass on the object being exposed to laser light, tape a piece of paper (5 cm x 5 cm) on the object. Then follow all steps in Part II of the PROCEDURE. The wind currents, as small as they may be, will create microscopic movements in the paper. These movements can be captured as stress lines after exposure, development, and viewing. Break a piece of hologram off the original hologram. See if the interference pattern can also be seen in the small piece of hologram.

Make a transmission hologram. This type needs laser light for viewing by projecting it onto a screen.

There may be a laser tech lab in the area to visit (Argonne National Lab, Fermi Lab, etc.).

Make a stress hologram with a heat source. Heating up one part of the object and then making a hologram of it will produce stress lines. Thin film can also be studied to see its relationship with interference patterns. A discussion of interference patterns will help to strengthen this unit.

REFERENCES, RESOURCES, VENDORS:

Integraf
P.O. Box 586
Lake Forest, IL 60045

The Photographer Formulary, Inc.
P.O. Box 5105
Missoula, MT 59806)

Science vendors

Holographic Museum
1134 W. Washington Blvd.
Chicago, IL 60607
(312) 226-1007

Science equipment suppliers

Central Scientific Company
11222 Melrose Ave.
Franklin Park, IL 60131-1364
(708) 451-0150

Science Kit & Borneal Labr.
777 East Park Drive
Tonawanda, NY 14150-6784
(800) 828-7777

Sargent-Welch
P.O. Box 1026
Skokie, IL 60076-1026
(800) 729-4368

Fisher Scientific-EMD
4901 W. LeMoyne Street
Chicago, IL 60651
(800) 621-4769

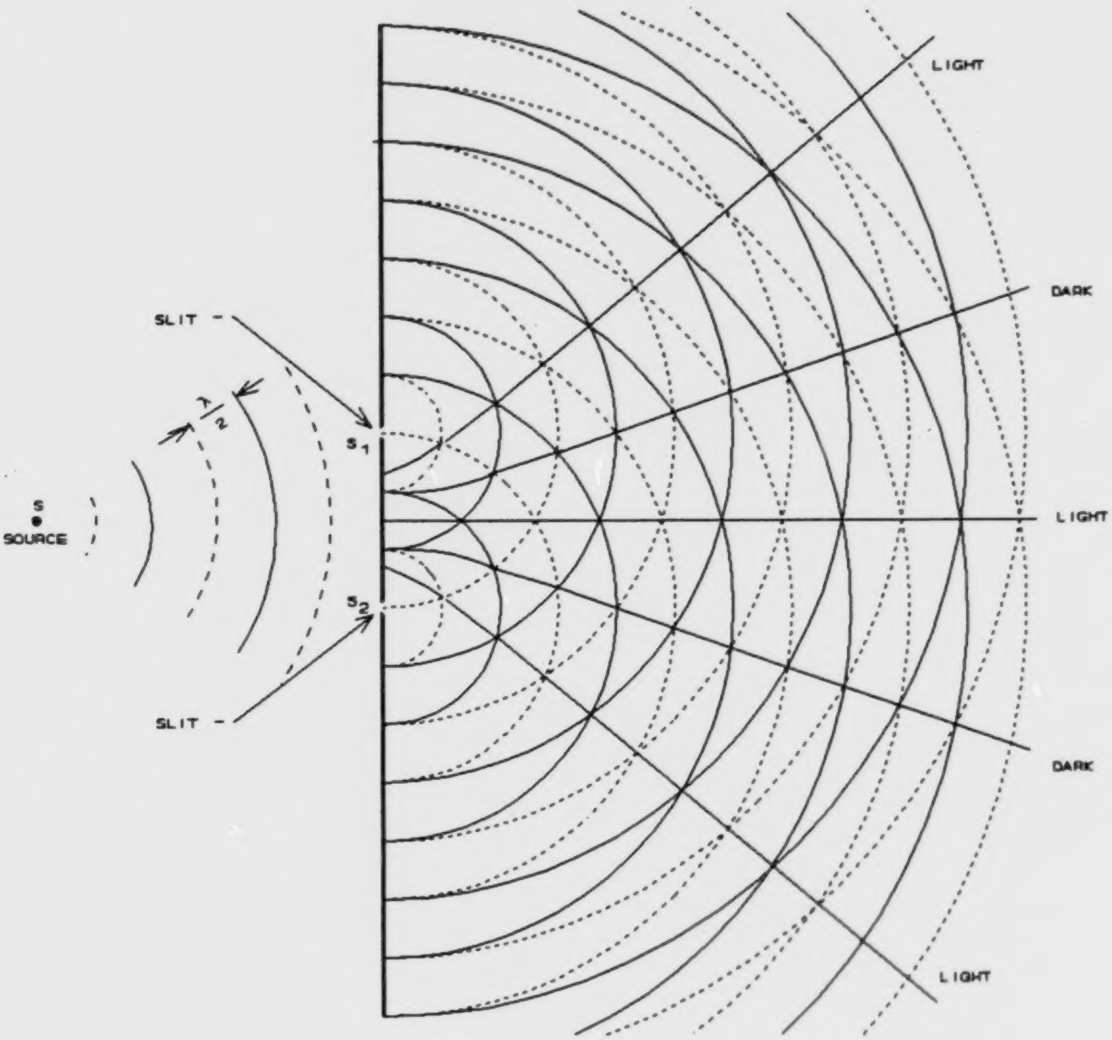

LIGHT
DARK
LIGHT
DARK
LIGHT
SLIT
SLIT
$\lambda/2$
S_1
S_2
S
SOURCE

Figure G-9-1

Young's Double Split Interference Pattern

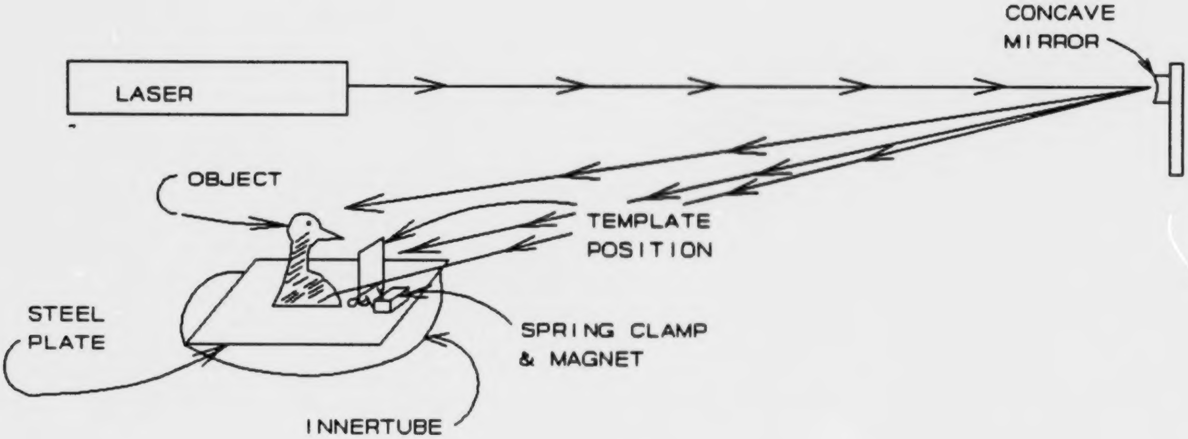

CONCAVE MIRROR
LASER
OBJECT
TEMPLATE POSITION
STEEL PLATE
SPRING CLAMP & MAGNET
INNERTUBE

Figure G-9-2

Holography Component Position Diagram

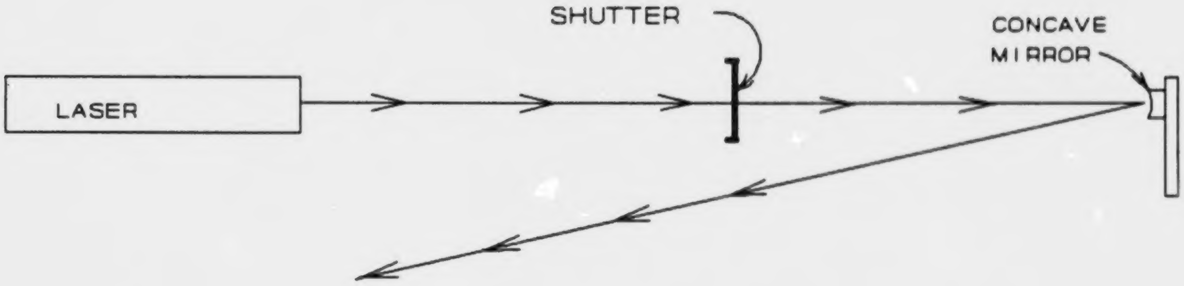

SHUTTER
CONCAVE
MIRROR
LASER

Figure G-9-3

Holography Shutter Position Diagram

REFLECTION HOLOGRAPHY POST-LAB QUESTIONS

1. What is a hologram?

2. What is the difference between a transmission hologram and a reflection hologram?

3. What does the acronym L.A.S.E.R. stand for?

4. What is the difference between constructive and destructive interference?

5. List five uses for lasers.

6. List three uses of holograms.

7. Why is it necessary there be no movement while exposing a hologram to the laser beam?

8. Why is the green night light an acceptable light source while developing a hologram?

9. What do stress lines indicate on the hologram?

10. What is the difference between a virtual and real image?

11. What is the difference between a hologram and an ordinary photograph?

12. What is the difference between coherent light and incoherent light?

13. What is the meaning of Monocromatic Waves?

14. What is the electromagnetic spectrum from longest wavelength to shortest wavelength?

15. What is the speed of the laser light in m/s?

16. How did changing the mass for each group of students affect the stress in the object?

REFLECTION HOLOGRAPHY MATHEMATICS WORKSHEET

Use a scientific calculator to solve the following (round t to the nearest 0.1 s, n to the nearest 1 mW):

Given: $t = 40\ (0.5)^n$; t is the exposure time;
n is the no. of mW

1. Complete the chart using the $\mathbf{y^n}$ function on your scientific calculator.

   (t is a function of n)

n	1	2	3	4	5	6
t						

2. Solve for n (to nearest 0.1 mW) given a value of t. Use the common logarithm **LOG** after dividing t by 40.

   ($t/40 = 10.5)^n$; $n=\frac{Log\ t/40}{Log\ 0.5}$)

n					
t	1	2	3	4	5

ACTIVITY 10: PHOTOSENSITIVE DEVICES (How They React to Changing Levels of Light)

TECHNOLOGICAL FRAMEWORK:

Photoconductive and photovoltaic devices have come into widespread use over the past few years. With the advent of solid state electronics, the voltage necessary to operate electrical circuits was significantly reduced. Along with this reduction in voltage came reduction in size. Photovoltaic arrays are now used to supply power to remote switching and booster stations for the communications industry. Photoconductive cells are used in most security (dust-to-dawn) lighting systems. Street lights are almost universally controlled by photoconductive cells. This allows for the most cost-effective use of lighting. Photovoltaic cells are used extensively to power devices such as calculators. These two types of photosensitive devices have had a powerful effect on our lifestyle.

PURPOSE:

To determine relationship between light intensity and resistance in a photoconductive cell

To determine relationship between light intensity, voltage, and current in a photovoltaic cell

To determine power output of a photovoltaic cell

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
Lumination
Direct current
Inverse Square Law

Technology:
Photoelectric effect
Electrical power
Photoconductive cells
Photovoltaic cells

Mathematics:
Graphing
Metric conversions

PRE-REQUISITES:

Photoelectric effect

D.C. fundamentals

Illumination

Two-dimension graphing

Metric conversions

MATERIAL, EQUIPMENT, APPARATUS:

Light source (100-watt bulb)
12 photovoltaic (solar) cells*
12 photoconductive (CdS) cells*
(12 K minimum at 1 ft cd. 250 maximum at 100 ft cd; 75 mW maximum power)
Digital multimeters
Light meters (Lux-im/m^2 and footcandles)
Metric tapes or meter sticks

(*Refer to vendors)

TIME FRAME: Two 50-minute periods

TEACHING STRATEGIES:	Group students by twos. Use the Physics/Electricity lab. Mathematics teacher will review graphing of functions. Physics teacher will cover photoelectric effect and illumination. Technology teacher will cover operation of photo cells and the lab.
TEACHING METHODOLOGY:	Review physics and math pre-requisites Lab demonstration Meter fundamentals Lab activity Post-lab session
FURTHER FIELDS OF INVESTIGATION:	Photographic exposure meters Dusk-to-dawn lighting Solar electric panels Solar-powered space vehicles Battery rechargers Solar calculators

PROCEDURE:

By connecting a photoconductive cell to an ohmmeter, it will be possible to measure the resistance of the cell in relationship to the level of light striking its surface. The amount of light may be determined using a light meter which measures in lux or foot-candles. As the light varies, the resistance changes in an inverse fashion.

By connecting a photovoltaic cell to an ammeter and a voltmeter, it will be possible to measure both the current flow and voltage produced by a photovoltaic cell in relationship to the amount of light striking it. After measuring both the current and voltage, it is possible to calculate the power using $P = VI$.

Part I. Photoconductive Cell

A. Set up photoconductive cell and the ohmmeter as shown in Figure G-10-1, "Photoconductive Cell Wiring Diagram."

B. Place a light source 10 cm from the photoconductive cell and record the resistance in megohms (col. C, Table G-10-1, "Photoelectric Effect Data Table").

C. Place a light meter directly in front of light source and record lumination in lux ($1m/m^2$) or footcandles (col. B, Table G-10-1).

D. Place the light source 20 cm from the cell and record the resistance in megohms (col. C, Table G-10-1). Place the light meter next to the cell, aiming it at the light source and record the lumination of the light source at 20 cm (col. B, Table G-10-1).

Note: It may be necessary to change the light distance from the cell. This will depend on the type of voltage, resistance, and current that is received.

E. Repeat step D for the distances of 40 cm, 60 cm, 80 cm, and 100 cm.

Part II. Photovoltaic Cell

A. Connect photovoltaic cell and meters as shown in Figure G-10-2, "Photovoltaic Cell Wiring Diagram."

Caution: The ammeter in this circuit is being connected without a load. It works with this circuit only because the output from the power supply (the photovoltaic cell) is so small that the internal resistance of the meter is great enough to act as a load. If the circuit was created with a more powerful source, it would destroy the ammeter.

1. Place the 100-watt bulb directly in front of and at 10 cm from the solar cell. Record the voltage and current in columns D and E, respectively, Table G-10-1.

   Note: The voltage should be in the tenth of a volt range, while the current will be in the microamp range.

2. Move the light source 20 cm from the cell and record the voltage and current in Table G-10-1.

3. Repeat the above procedure at distances of 40 cm, 60 cm, 80 cm, and 100 cm from the solar cell.

B. Calculate the power output of the solar cell at each distance 10 cm-100 cm. Use the measured voltage and current for each distance in the formula P = VI. (Record the calculated value in column F, Table G-10-1.)

ANTICIPATED PROBLEMS:	Check for proper meter connections and meter ranges. Constant light source necessary. Proper alignment of light source.
METHODS OF EVALUATION:	Observation during the lab activity Post-lab write-up and graphs Selected quiz items for the Unit Test
FOLLOW-UP ACTIVITIES:	The students may set up an automated system using photo cells to operate it. A combination of several solar cells can be used to power a small motor. A class discussion or written report addressing solar panels or solar heating can be used to enhance this activity.
REFERENCES, RESOURCES, VENDORS:	Industrial Arts Supply (solar cell kit #10) 5724 W. 36th Street Minneapolis, MN 55416-2594 (612-920-7393) Radio Shack Aidex Corporation 1802 N. Division St. Morris, IL 60450 (800) 251-9935

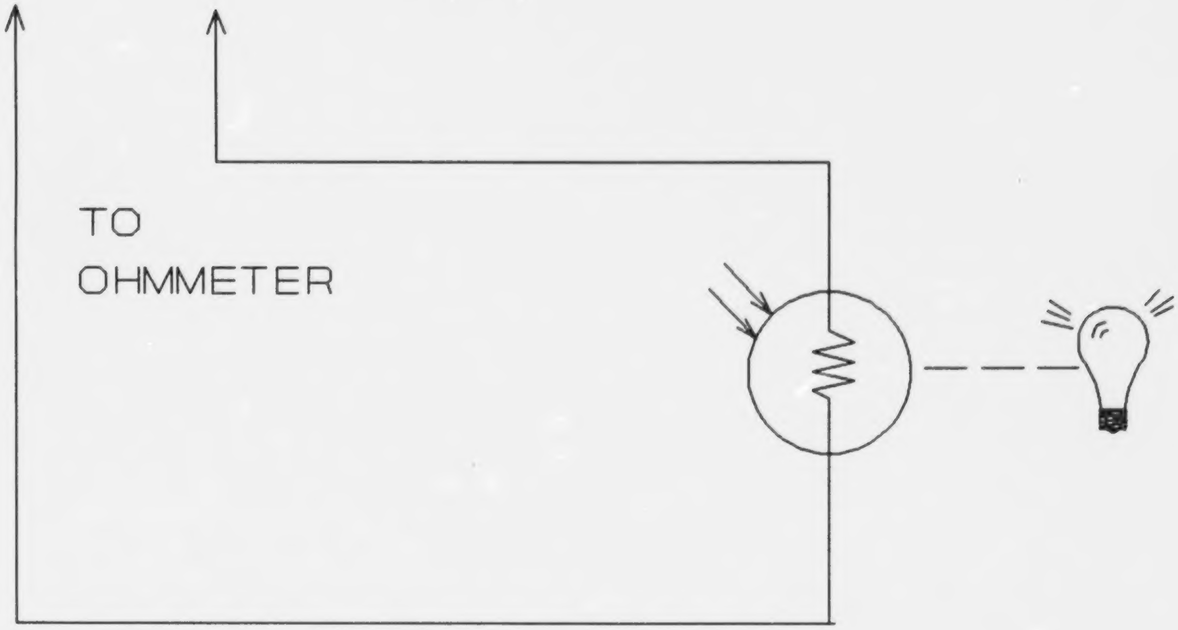


Figure G-10-1

Photoconductive Cell Wiring Diagram

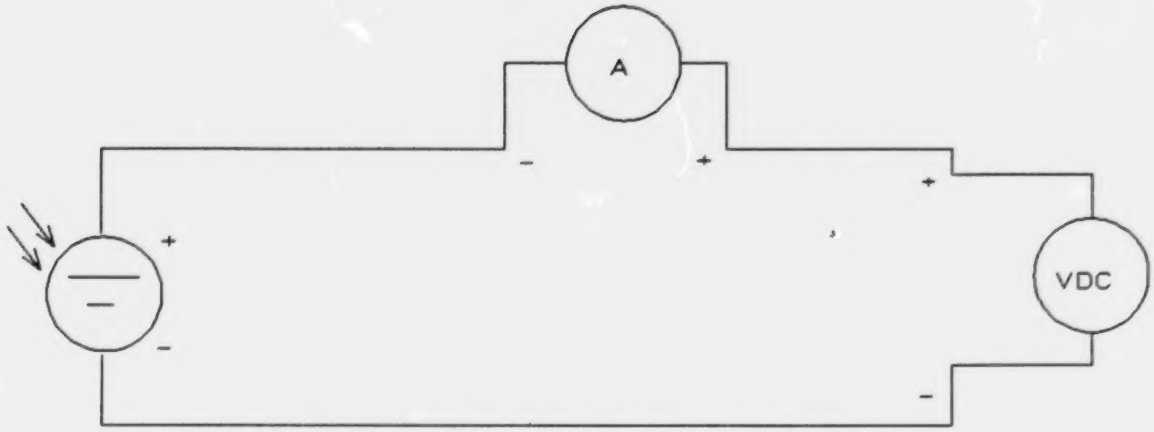


Figure G-10-2

Photovoltaic Cell Wiring Diagram

Table G-10-1

Photoelectric Effect Data Table

A	B	C	D	E	F
10 cm					
20 cm					
40 cm					
60 cm					
80 cm					
100 cm					

PHOTOELECTRIC EFFECT POST-LAB QUESTIONS

1. Explain the difference between a photoconductive cell and a photovoltaic cell.

2. On a sheet of graph paper, graph resistance versus illumination with illumination on the horizontal axis.

   As the illumination increases, what happens to the resistance of the photoconductive cell?

3. On a separate sheet of graph paper, graph voltage output versus illumination with lumination on the horizontal axis.

   As the illumination increases, what happens to the voltage of the photovoltaic cell?

4. On a separate sheet of graph paper, graph current versus illumination with illumination on the horizontal axis.

   As the illumination decreases, what happens to the current flow through the photovoltaic cell?

5. List three different uses of photo cells in everyday life.

6. Would focusing a pencil of light onto the photovoltaic cell increase your power output? Explain your answer.

7. Explain the photoelectric effect in your own words.

PHOTOSENSITIVE DEVICES MATHEMATICS WORKSHEET

Inverse Variation: $y = k(\frac{1}{x})$, where k is the constant of proportionality and $k = yx$.

Sample:

If y is inversely proportional to x, and y is 8 when x is 3, find y when x is 12.

Solution: $y = k(\frac{1}{x})$; $8 = k(\frac{1}{3}) \rightarrow k = 24$

$$y = 24(\frac{1}{x});\ y = 24(\frac{1}{12})$$

$$y = 2$$

Solve:

1. If y varies inversely as x, and y is 385 when x is 832, find y when x is 226.

2. If y is inversely proportional to x, how does y change when x is doubled?

3. If y is inversely proportional to x, fill in the missing values.

x	306	622	?
y	125	?	418

Hint: If $k = y_1x_1$, then $k = y_2x_2$; thus, $y_1x_1 = y_2x_2$.

The "inverse square law" states that the intensity of illumination on the surface is inversely proportional to the square of the distance between the source and the surface.

$I = k(\frac{1}{d^2})$, where k is a constant of proportionality and $k = Id^2$.

Solve:

1. A certain light source produces an illumination of 800 lux (a lux is 1 lumen per square meter) on a surface. Find the illumination on that surface if the distance to the light source is doubled.

2. A light source located 2.75 m from a surface produces an illumination of 528 lux on that surface. Find the illumination if the distance is changed to 1.55 m.

3. A light source located 7.50 m from a surface produces an illumination of 426 lux on that surface. At what distance must that light be placed to give an illumination of 850 lux?

ACTIVITY 11: CURVED MIRRORS

TECHNOLOGICAL FRAMEWORK: The basic component of the parabola which is used in industry is its ability to concentrate rays which strike it. Parabolas have been used for many years in collecting radio waves. In recent years, parabolic dishes have become commonplace in backyards with the advent of satellite transmission of TV signals. Solar collectors using the parabolic shape concentrate the radiant energy at a focal point which allows for easy collection. As the technology of heat transfer becomes more efficient, the use of the parabola will become more important.

PURPOSE: To develop a parabolic curve.

To calculate the focal point of a parabolic curve.

To construct a parabolic reflector.

To measure the light intensity and temperature at the focal point.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
- Reflection
- Curved mirrors
- Temperature
- Light intensity
- Conversion factor
- Ray diagrams

Technology:
- Parabolic antenna
- Concentrating solar collectors

Mathematics:
- Parabola:
  - characteristics
  - sketching
  - writing equations
- Circle:
  - radius
  - diameter
  - circumference

PRE-REQUISITES:

Physics:
- Temperature conversions
- Laws of reflection
- Use of light meter
- Light intensity
- Properties of waves

Mathematics:
- Coordinate plane formula
- Formula manipulation
- Circumference

MATERIALS, EQUIPMENT, APPARATUS:

- Mirror-finish mylar
- Poster board
- Thermometers
- Spray adhesive
- Felt-tip pens
- Light intensity meter
- Utility knife
- Graph paper (mm)
- Ruler (mm)
- Tape

TIME FRAME: Two 50-minute periods

TEACHING STRATEGIES:

Split the class into groups of 3 or 4.

Location:

(a) Technology lab for development and and construction stages

(b) Outdoors for testing

Mathematics teacher - lecture/worksheet on parabolas

Technology and Physics teachers - development and construction of parabolic reflector

Physics teacher - cover pre-requisites and testing

TEACHING METHODOLOGY:

Review physics pre-requisites and math concepts
Construction demonstration model
Group problem solving and self-evaluation
Data collection techniques
Actual construction of a parabolic reflector
Lab write-up activity
Post-lab session

FURTHER FIELDS OF INVESTIGATION:

Concentrating solar collectors in the energy industry and home heating

Satellite dishes used in communications

Reflector telescopes

Curved mirrors used for applying makeup

Curved mirrors used in store security

PROCEDURE: This activity will require a total TEAM effort by the members of each group. It is necessary to develop the parabola mathematically (be careful when doing the calculations on a calculator). Use poster board when doing the actual construction of the parts of the parabolic reflector. It is suggested that each part of the activity be read in its entirety before proceeding with the steps.

Part I. Development of a Parabolic Curve

A. Each group will develop its own parabola given values of a and b (refer to Figure G-11-1, "Parabola Component Identification").

Note: Use a = 40 cm for each group and b = 20 cm; 15 cm; 10 cm.

B. Using the formula $Y = X^2/(4p)$. Find p using $X = a/2$ and $Y = b$.

C. Rewrite the formula with the p value now in it and complete Figure G-11-2, "Parabola/Coordinate T-Chart" by solving for the values of Y (nearest 0.1 cm).

D. Using a piece of poster board, draw a coordinate system to scale and plot points using the values from Figure G-11-2. (The points are labeled A through E for reference purposes.) For every point you locate in quadrant I, there is an image point in quadrant II to complete the parabola. (Refer to Figure G-11-3, "Parabola Scaled Drawing.")

Part II. Construction of a Parabolic Reflector

Note: The reflector will be built in sections, each being 1/4 of the actual curve.

A. Connect the points you plotted in Part I (D) with a smooth curve in quadrant I only (use a string or flexible ruler).

B. Use a utility knife to cut out the curve from points A to E (also cut along the Y axis). (Refer to Figure G-11-4, "Parabola Scaled Drawing Cut-Out.")

C. To measure the length of the arc from A to E:

1. Lay a string or flexible ruler along the curve from A to E.

2. Use a felt-tip marker to mark points A through E on the string or ruler.

D. On a sheet of poster board, draw in a set of axes and place the string on the Y-axis with point A set at (0.0). Mark points B through E on the Y-axis. (Refer to Figure G-11-5, "Vertical Axis Point Location Diagram.")

E. Using Figure G-11-2 (see Part I, C), each X value is the radius of a circle and you are to compute the circumference using $C = 2\pi r$. Divide the circumference by 4 (each section is 1/4 of the curve). Divide your answer by 2 and record this as X in Figure G-11-6 (".125 Times Circumference Chart") (nearest 0.1 cm).

F. On the poster board layout from step D:

1. Use a compass and with point A as the center point, draw an arc from each of the points B-E as in Figure G-11-7 ("Plot of Circumference Data").

2. Mark off distances on each arc from points B-E equal to the X lengths in Figure G-11-6 from step E (points B'-E').

3. Use a string or flexible ruler to help you locate points B'-E' and to also draw in a smooth curve through points A'-E'. Cut out the pattern drawn. (Refer to Figure G-11-7.)

G. Transfer the cut-out section to poster board and trace the pattern twice (side-by-side vertically as shown). Repeat this process to get three more sections for the parabolic reflector. (Refer to Figure G-11-8, "One-Fourth Parabola Section Layout.")

H. For each of the four sections, use a spray adhesive to glue pieces of mylar to one side of each section--trim excess mylar from each section using the utility knife.

I. Use a compass to draw a circle (6 cm diameter) on a piece of poster board and cut out the circle formed.

J. In the center of the circle, cut out a hole large enough to support a tube wide enough to support the test equipment (probe, thermometer, etc.). (Refer to Figure G-11-9, "Meter Support Diagram.")

K. On each of the four sections formed in step H, cut off approximately 0.5 cm from each tip.

L. Tape the four sections together, placing the tape on the non-mylar sides. (Refer to Figure G-11-10, "Parabola Assembly.)

M. Use the round disk from step J as a base for the parabolic reflector and fasten it to the top of the INVERTED parabolic reflector as shown. (Be sure the tube in the base is perpendicular to the table top on which you place the inverted reflector.) (Refer to Figure G-11-11, "Meter Support/Parabola Assembly Diagram.")

Part III. Testing the Parabolic Reflector Outside

Safety Warning: The reflector could be harmful to your eyes; high temperature at the focal point.

A. Using a light meter, record the ambient light intensity of non-focused sun light.

__________footcandles

B. Using a light meter, record the light intensity at the focal point of the reflector.

__________footcandles

C. Using a thermometer, record the ambient temperature.

__________°C

D. Using a thermometer, record the temperature at the focal point.

__________°C

ANTICIPATED PROBLEMS:

Accuracy during the construction phase will affect the testing outcomes

Monitor the mathematics involved

METHODS OF EVALUATION:

Check the math calculations during the development process under PROCEDURE

Observation during the construction process

Post-lab write-up and questionnaire

Quiz items on the Unit Test

FOLLOW-UP ACTIVITIES:

An apparatus can be set up to calculate the speed of light. Some of the history of how the speed of light has been calculated may be discussed. Radio telescopes are also designed to reflect radio waves to a focal point and are very similar in design to parabolic reflectors. Additional problems on frequency and wavelength of electromagnetic radiation may also enhance this unit.

REFERENCES, RESOURCES, VENDORS:

Industrial Arts School Supply (IASCO)
5724 W. 36th Street
Minneapolis, MN 55416-2594

Central Scientific Company (CENCO)
11222 Melrose Avenue
Franklin Park, IL 60131-1361
9708) 451-0150

Sargent Welch Scientific Company
P.O. Box 1026
Skokie, IL 60076-8026
(800) SARGENT

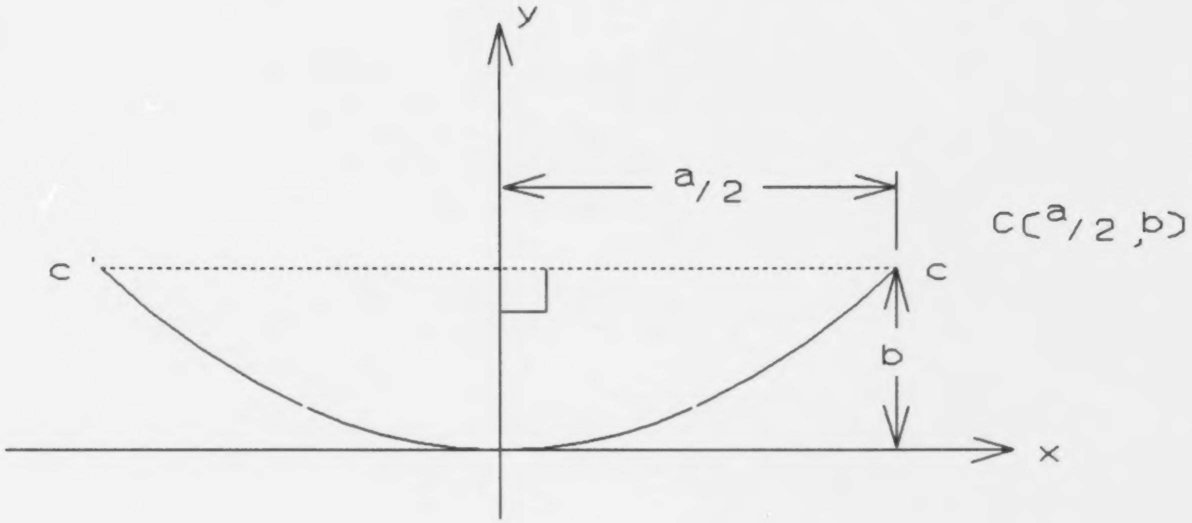


Figure G-11-1

Parabola Component Identification

POINT	X	Y
A	0	
B	5	
C	10	
D	15	
E	20	

Figure G-11-2

Parabola/Coordinate T-Chart

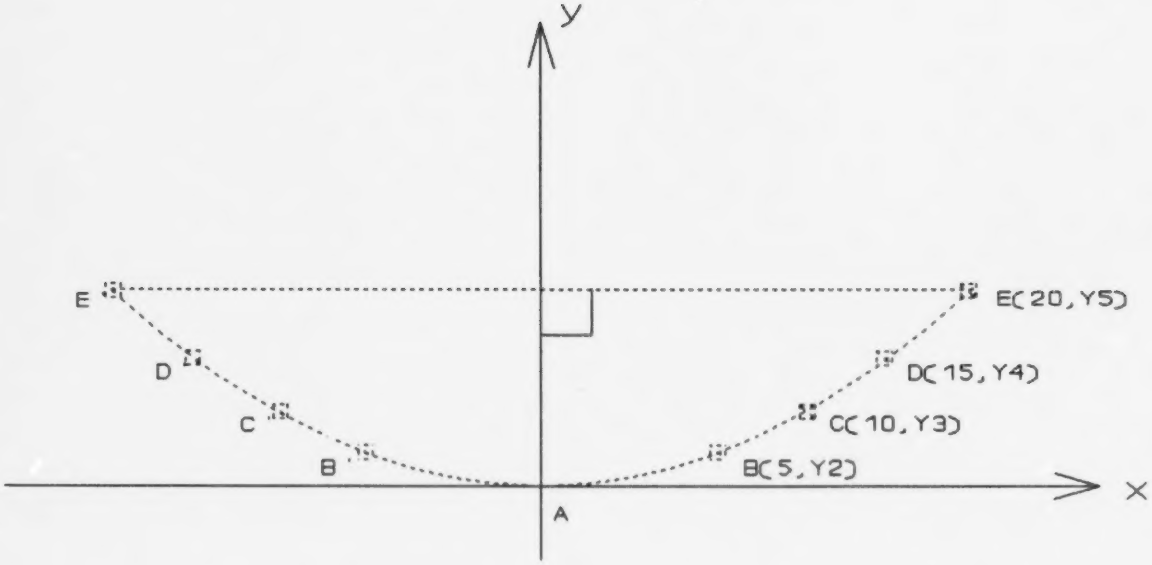

y
E
D
C
B
A
X
E(20,Y5)
D(15,Y4)
C(10,Y3)
B(5,Y2)

Figure G-11-3

Parabola Scaled Drawing

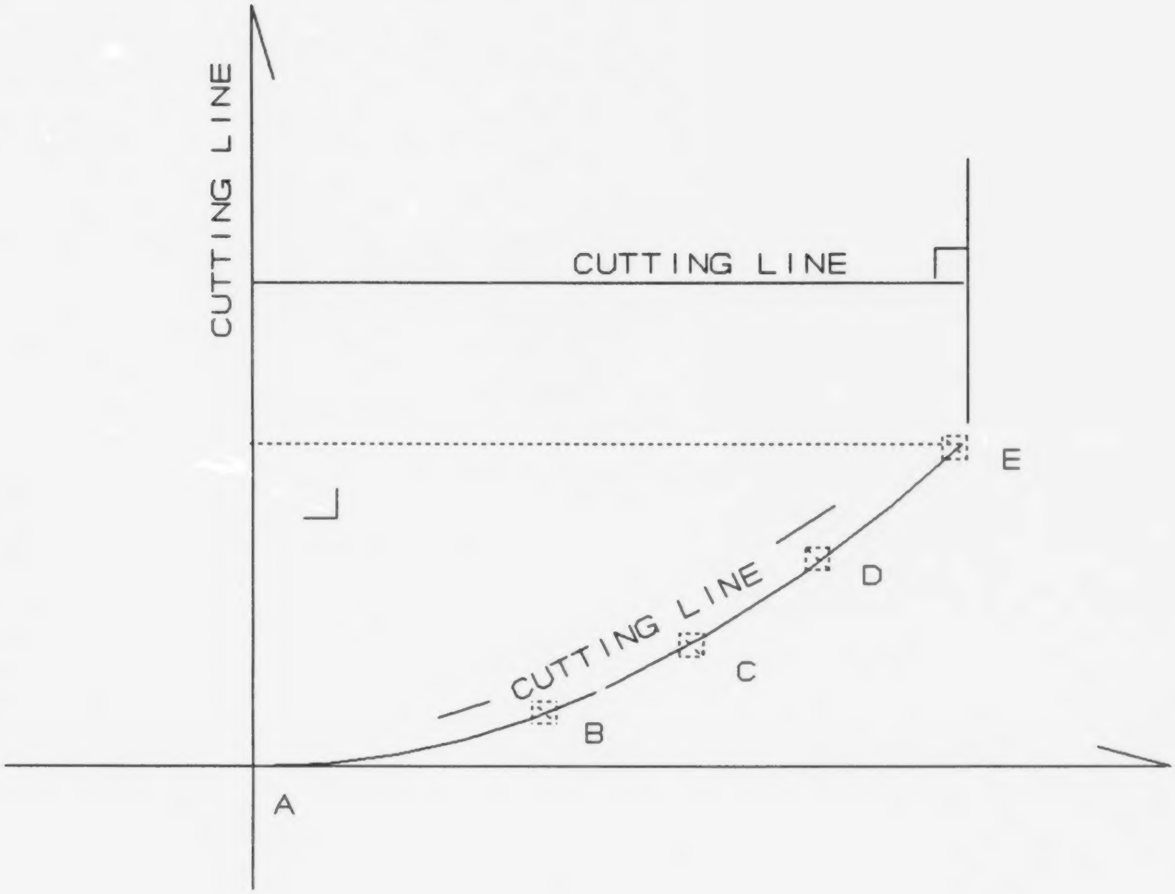

CUTTING LINE
CUTTING LINE
CUTTING LINE
A
B
C
D
E

Figure G-11-4

Parabola Scaled Drawing Cut-Out

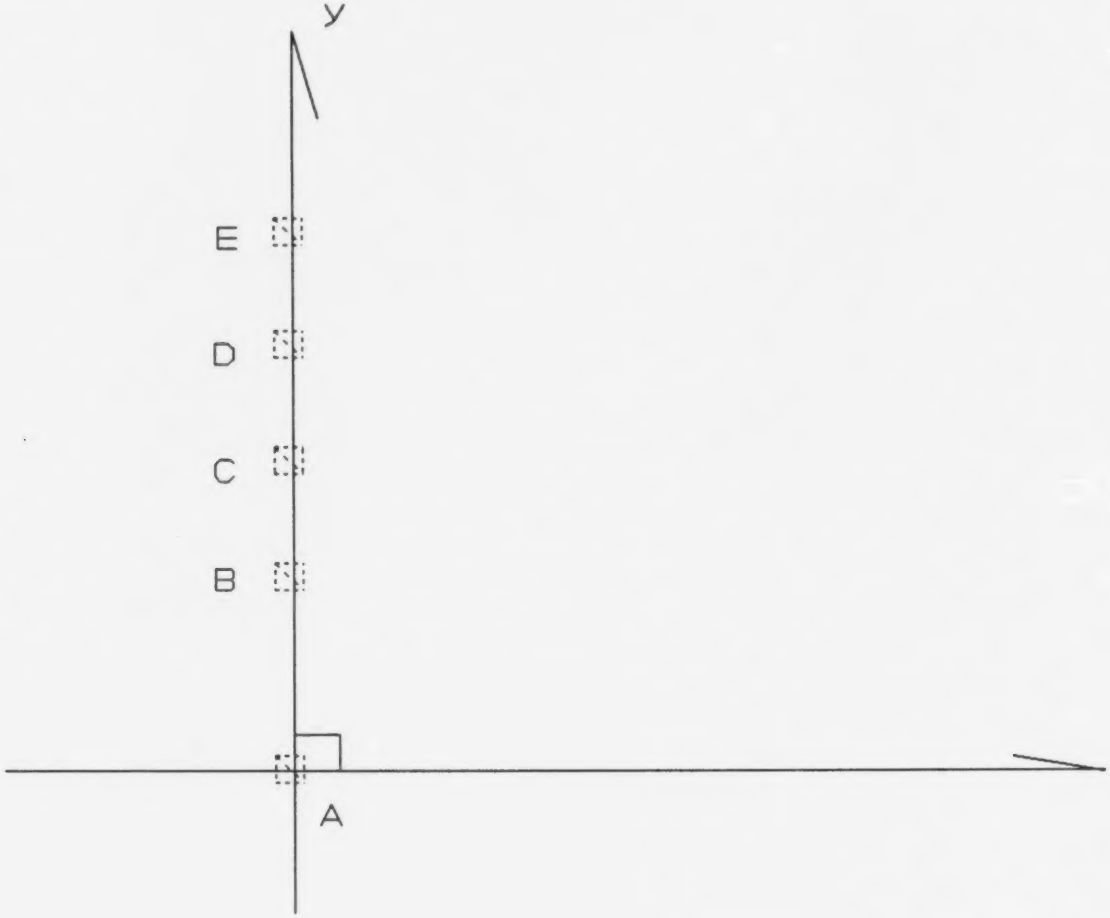


Figure G-11-5

Vertical Axis Point Location Diagram

POINT	X
A'	0
B'	
C'	
D'	
E'	

Figure G-11-6

.125 Time Circumference Chart

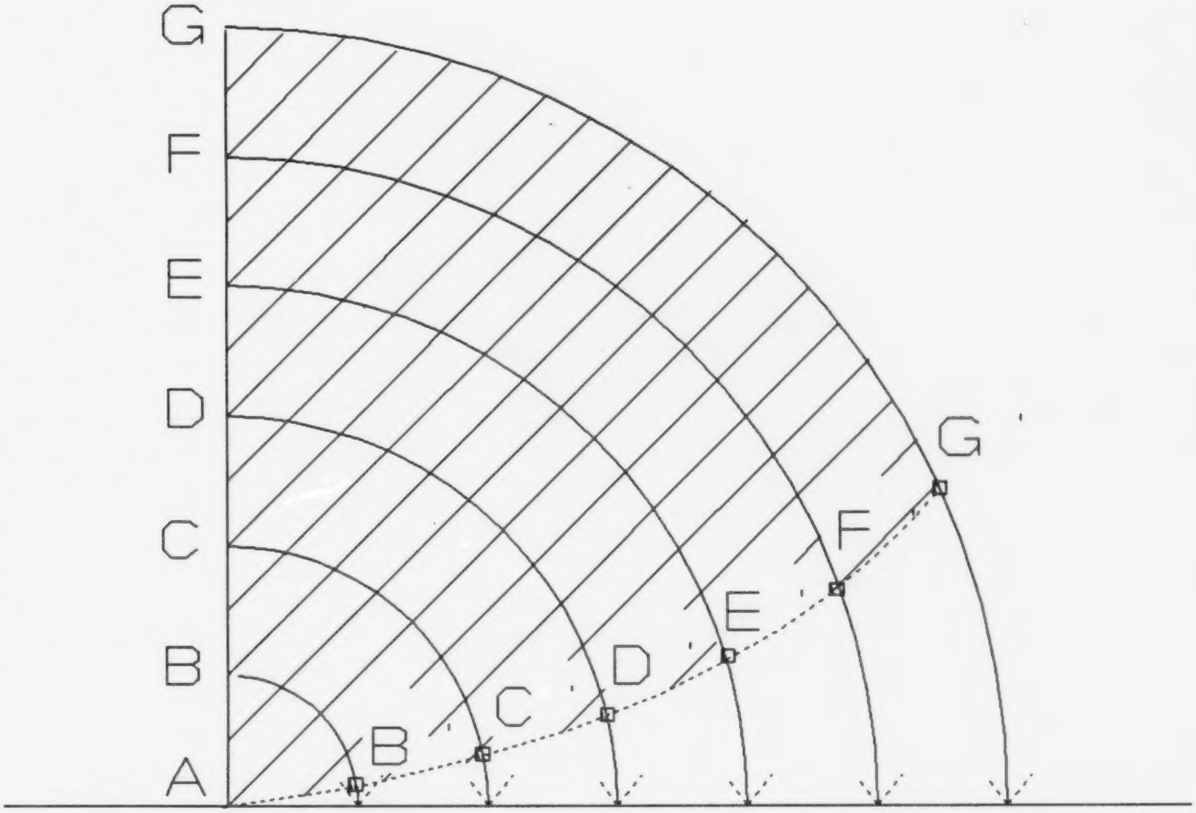


Figure G-11-7

Plot of Circumference Data

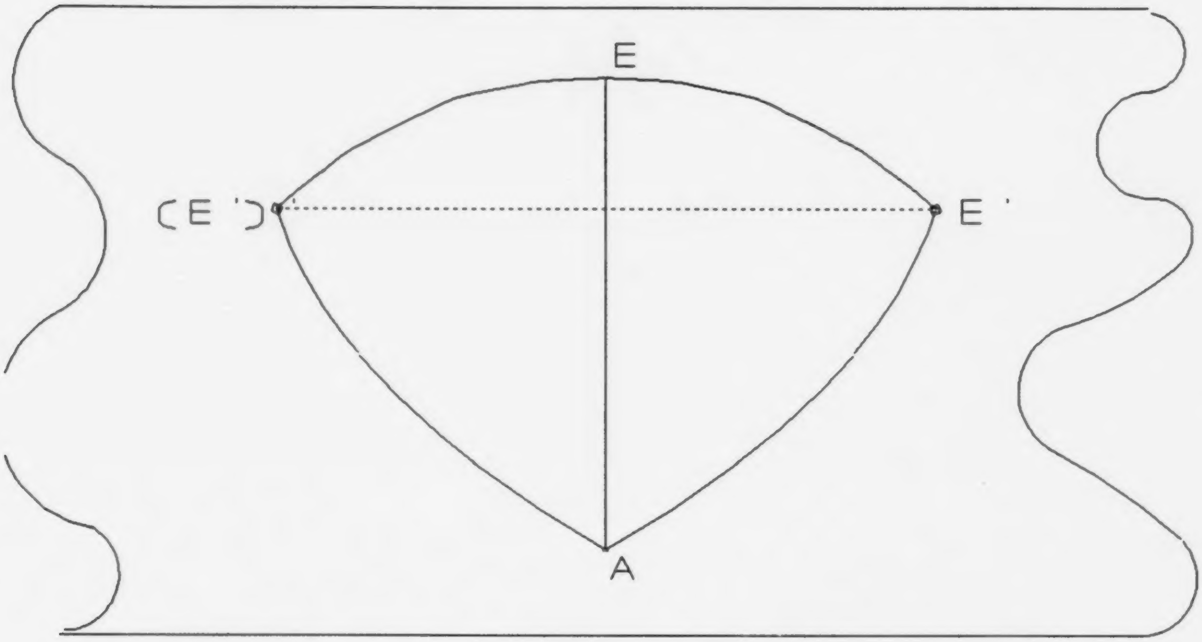


Figure G-11-8

One-Fourth Parabola Section Layout

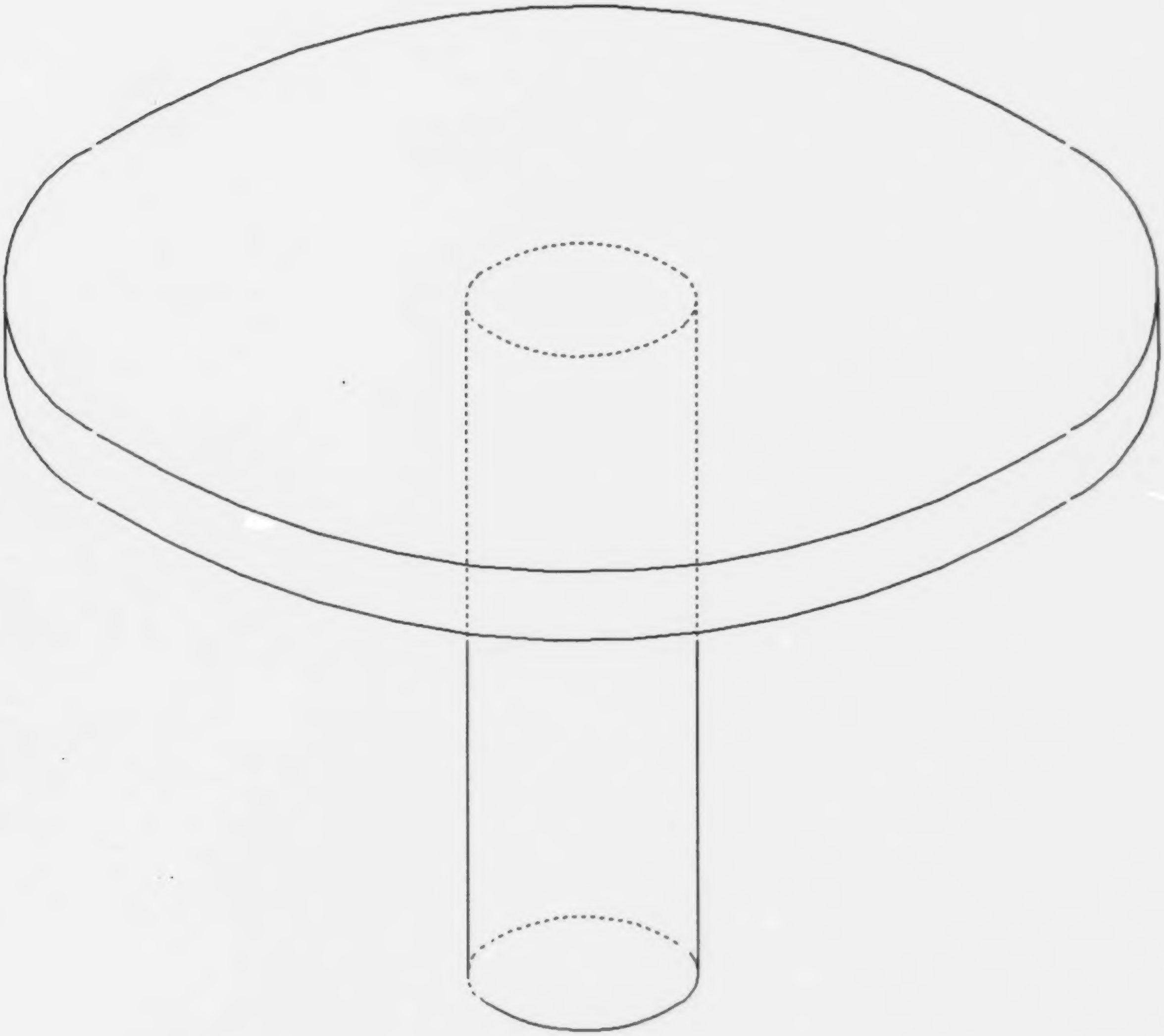


Figure G-11-9

Meter Support Diagram

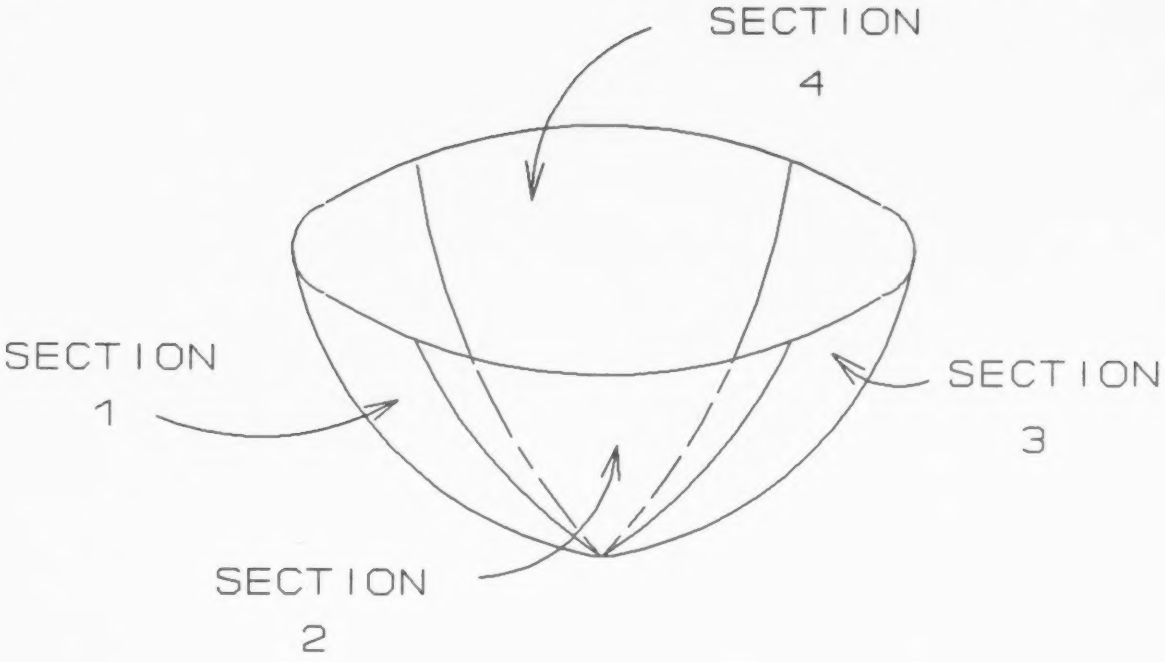

SECTION 4
SECTION 1
SECTION 3
SECTION 2

Figure G-11-10

Parabola Assembly

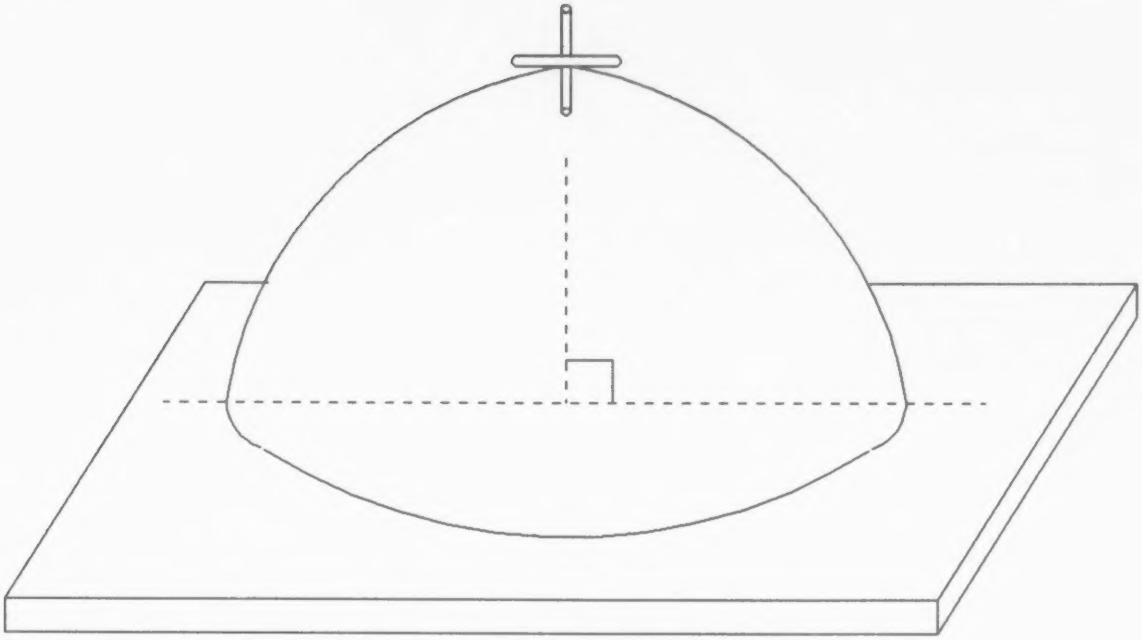
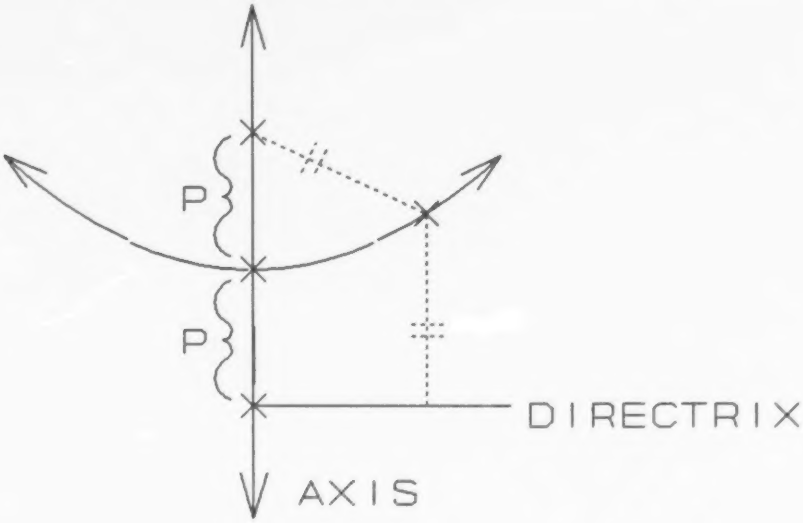


Figure G-11-11

Meter Support/Parabola Assembly Diagram

PARABOLA MATHEMATICS SUPPLEMENT

A parabola is a set of points in a plane, each of which is equidistant from a fixed point (called a "Focus") and a fixed line (called a "Directrix"). Refer to the diagram below:



The mathematical formula for a parabola with a vertical axis of symmetry is:

$$Y = \frac{1}{4P}(X-h)^2 + k$$

where the vertex is (h,k); P is the distance from the vertex to the Focus; and X = h is the axis.

****

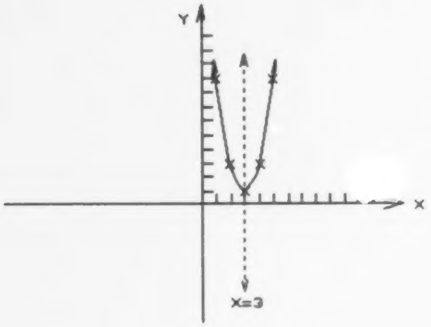
In mathematics, you will study a parabola when you work with Functions (a "Function" is a set of ordered pairs where no two pairs have the same first value in the pair).

$Y = a(X - h)^2 + k$ or $Y = aX^2 + bX + c$ are the two formulas you would most often work with when setting up a T-Chart for your graphing of points.

****

$Y = (2X - 3)^2 + 1$ describes a parabola whose vertex is at (3,1) and the axis is at $X = 3$. See the T-Chart and accompanying values along with the sketched graph.

x	y
0	19
1	9
2	3
3	1
4	3
5	9
6	19
7	33
etc.	

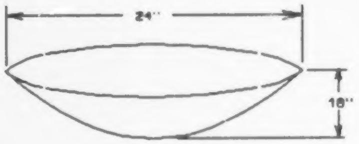


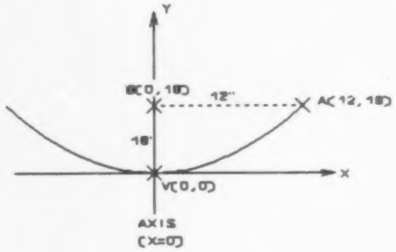
Given:

$y = a\ (X - h)^2 + k \qquad h=0,\ k=0$
$y = ax^2$; [vertex is (0,0)]
$18 = a\ (12)^2$ (point (12,18) is on the parabola)
$18 = a\ (144)$

$$\frac{18}{144} = a$$

$$a = \frac{1}{8}$$





The equation (formula) for the above parabola is $y = \frac{1}{8}x^2$ where (x,y) are points on the curve.
Use a T-Chart to find more points:

x	0	1	2	3	4	5	6
y							

****

To find the Focus of the parabola:

$y = \frac{1}{8} x^2 \rightarrow y = \frac{1}{8} (x - 0)^2 + 0$; $[y = \frac{1}{4p} (X - h)^2 + k]$

$y = \frac{1}{4(2)} (x - 0)^2 + 0$ where: $h = 0$, $k = 0$, and $P = 2$.

CURVED MIRRORS POST-LAB QUESTIONS

1. Express the ratio of Focal Point Light Intensity to Ambient Light Intensity as a decimal to the nearest 0.001.

2. Express the ratio of Focal Point Temperature to Ambient Temperature as a decimal to the nearest 0.001.

3. What conclusion can you reach from the increase in temperature versus the increase in light intensity?

4. Sketch a ray diagram of sunlight striking a parabolic curve.

5. Sketch a ray diagram of sunlight striking a spherical curve.

6. What comparisons can be reached concerning the two ray diagrams?

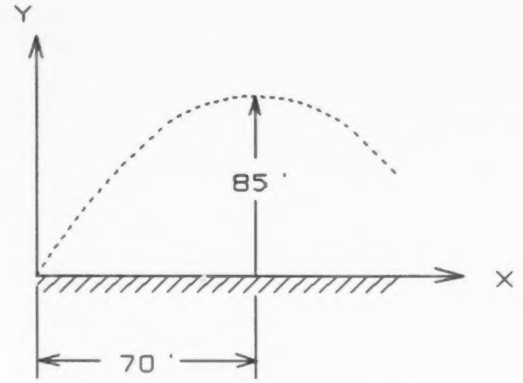
7. Using the Ambient and Focal Point Temperature from Part II of the PROCEDURE, convert the readings to degrees Fahrenheit.

8. List at least three every-day applications of curved dishes or mirrors (parabolic or non-parabolic).

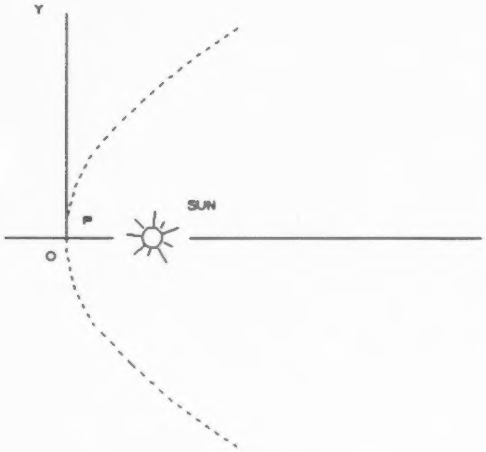
CURVED MIRROR MATHEMATICS WORKSHEET

Solve the following problems on applications of parabolic curves:

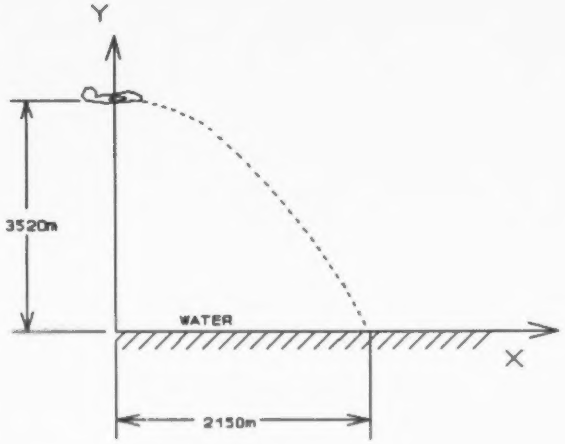
1. A ball thrown into the air will, neglecting air resistance, follow a parabolic path. Write the equation of the path, taking axes as shown. Use your equation to find the height of the ball when it is at a horizontal distance of 95 ft. from 0.



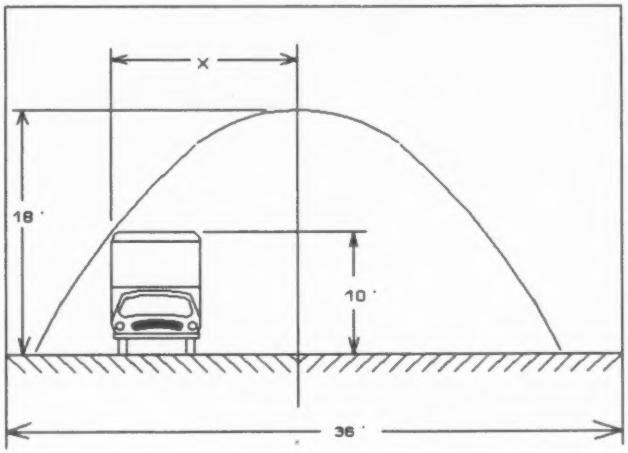
2. Some comets follow a parabolic orbit with the sun at the focal point. Taking axes as shown, write the equation of the path if the distance **p** is 75 million kilometers.



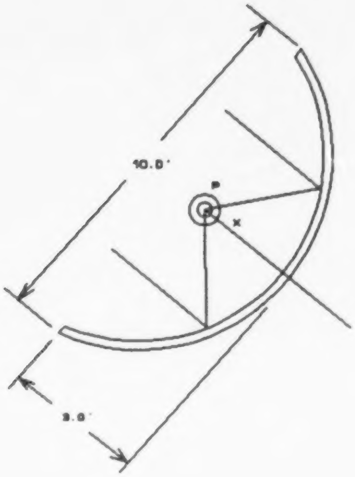
3. An object dropped from a moving aircraft will follow a parabolic path if air resistance is negligible. A weather instrument released at a height of 3,520 m is observed to strike the water at a distance of 2,150 m from the point of release. Write the equation of the path, taking axes as shown. Find the height of the instrument when **x** is 1000 m.



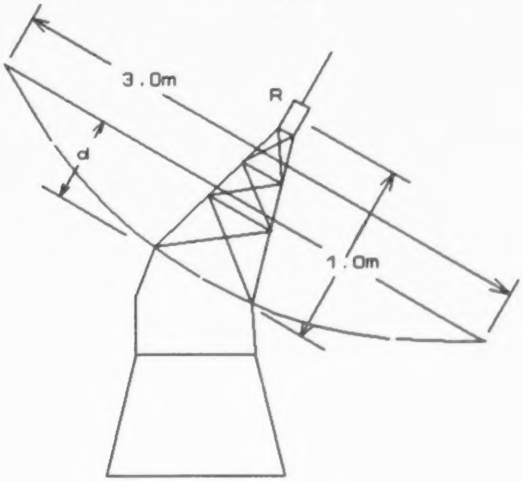
4. A 10-ft-high truck passes under a parabolic arch. Find the maximum distance **x** that the side of the truck can be from the center of the road.



5. A certain solar collector consists of a long panel of polished steel bent into a parabolic shape which focuses sunlight onto a pipe **P** at the focal point of the parabola. At what distance **x** should the pipe be placed?



6. A parabolic collector for receiving television signals from a satellite is shown below. The receiver **R** is at the focus, 1.0 m from the vertex. Find the depth **d** of the collector.



ACTIVITY 12: SENSORS IN AN AUTOMATED INDUSTRIAL SYSTEM

TECHNOLOGICAL FRAMEWORK:

Sensors have become a very important facet of our daily lives. In simply driving a car, there are many sensors involved, from the simple devices as a gas gauge to the much more complicated devices used for measuring the air-fuel mixture entering the intake manifold. Sensors can be found in a variety of places. Modern public washrooms use photosensors to turn the water on and off when you go to wash your hands. Modern business and industry runs on sensors. Strain gauges are used to allow robots to pick up such fragile things as eggs without damage. Temperature sensors are in constant use to determine not only comfort within buildings but also to monitor operating systems. Gas sensors are used as safety devices which protect and save lives.

The list of sensors is almost endless. Suffice it to say that sensors are now and will be in the future a very important part of our lives. It is therefore critical that people understand not only how sensors are used but also how they work. This will allow for expanded application of existing sensors, as well as the development of new types of sensors to meet different demands.

PURPOSE:

To demonstrate the application of sensing devices in an automated system.

To assemble an automated system using a given model.

To apply Physics concepts to certain parts of an automated system.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.

- The principles of scientific research and their application in simple research projects.

- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
  Rotary motion:
    angular acceleration
    angular velocity
  Specific heat
  Torque
  Friction
  Acceleration due to gravity
  Kinetic Energy
  Potential energy
  Ohm's Law
  Illumination

Mathematics:
  Ratios and proportions
  Graphing of functions

Technology:
  Robotics
  Computer control
  Stepping motors
  Computer-aided manufacturing
  Sensors

PRE-REQUISITES:

Lab activities on sensors:
  Thermistor, photo cells, fiber optics

Computer operation

Force; Torque; Angular velocity and acceleration, Angular displacement; Conservation of energy; Resistance; Error analysis; Testing equipment

Graphing of functions

MATERIALS, EQUIPMENT, APPARATUS: See respective sections under Procedures 1 and 2.

TIME FRAME: See respective sections under Procedures 1 and 2.

TEACHING STRATEGIES:

The Physics and Technology teachers will demonstrate the Automated System.

The Physics teacher will conduct Procedure 3.

The Technology teacher will conduct Procedure 2.

The students will be placed into teams of three and be assigned tasks in Procedure 2.

This activity can be used as a stand-alone activity. The instructor(s) can follow the lab step-by-step which would result in a duplication of the demonstration work cell. The Physics and Technology activities contained herein were developed to accompany the demonstration cell. Depending on the skills and equipment available, the instructor(s) may vary from the activities in this lab activity. Those variances may necessitate changes in the Physics activities as well as the lab write-ups. The development of this activity was intended to be a starting point in the hope that each individual system and instructor would make changes and improvements to meet their specific skills and needs.

TEACHING STRATEGIES:

The Technology lab will be used for set-up and operation of automated system.

The Physics lab will be used for running parallel experiments and analysis of data.

Explain lab write-ups for Procedure 2.

Testing the automated system.

FURTHER FIELDS OF INVESTIGATION:

Manufacturing of paging devices

Manufacturing of automobiles

Compliance with OSHA regulations

Fire safety

Energy efficiency

FOLLOW-UP ACTIVITIES:

Watch the film "Robotic Revolution" produced by National Geographic. This film will educate the viewer on what a robot can and cannot do and also explores the social implications of robots in the workplace. The video production number is 51193, and the 16 mm film production number is 50223. To further enhance this activity, take a field trip to a local manufacturing company which has an automated system using robots and various types of sensors. Robotic systems can be found in automobile manufacturing plants, watch-making assembly lines, stocking boxes in warehouses, and assisting in surgery.

REFERENCES, RESOURCES, VENDORS:

Motorola

Ford, GM, Chrysler, et al.
(i.e., automobile industries, Automated Systems Division)

3M

Aidex Corporation
1802 N. Division St.
Morris, IL 60540
(800) 251-9935

Energy Concepts, Inc.
7440 No. Long Avenue
Skokie, IL 60077
(708) 283-4422

Radio Shack

Eshed Robotec
P.O. Box 13234
Tel Aviv, Israel

PROCEDURE 1: Demonstration of an Automated Industrial System

The model demonstrated for the class will incorporate use of the SCORBOT ER-III Robot with a conveyor belt and a SpectraLIGHT (CNC) Lathe. The following information will outline what takes place at each station in the demonstration, time frame needed, and materials necessary.

MATERIALS, EQUIPMENT, APPARATUS:

SCORBOT ER-III, Slidebase, and Software from Eshed Robotec (P.O. Box 13234, Tel-Aviv, Israel)
IBM computer or compatible
SpectraLIGHT CNC Lathe and software from Light Machines Corporation (Manchester, NH)
Apple IIe or Apple IIGS computer
Pieces of 3/4" aluminum rod
Thermistor (Radio Shack part #271-110)
22-gauge stranded wire
Metal block
Conveyor belt from Eshed Robotec
AIM power supply adaptor, model #38-305BX
1 infrared sensor
2 relays (12 VDC, 40 mW from GS Electronics, catalog #D1-967)
Heat lamp (100-150 watts)
1 photoconductive cell and light source
1 small fan (squirrel cage type)
1 microswitch
Rotary table
Air brush (optional)

TIME FRAME: One 50-minute period

OUTLINE: With the software for the SpectraLIGHT loaded in the Apple computer, operator will turn a piece of aluminum bar on the lathe.

With the softwares for the SCORBOT ER-III loaded in the IBM computer, operator will load the demo program called CELL.

When the program is run (GO), the following will be demonstrated:

Station 1--The robot will pick up the piece of turned rod from the lathe's chuck.

Station 2--The robot will load the part onto a specially prepared carrier.

Station 3--The robot will pick up the carrier and bring it to the conveyor belt. The conveyor belt will then turn on and take the carrier to an infrared sensor which will turn off the conveyor belt. At this point, the heat lamp will turn on and proceed to heat the turned part of aluminum rod which was placed over a thermistor on the metal carrier. When the part is heated to temperature, the heat lamp turns off and the conveyor belt turns on.

Station 4--The conveyor belt takes the heated part on its carrier to a photoconductive cell. The carrier breaks the light beam, causing the conveyor belt to stop and a small fan to turn on. The fan will cool the part to temperature, causing the fan to turn off and the conveyor belt to turn on.

Station 5--The conveyor will bring the part on its carrier to a microswitch. When the switch is activated, the conveyor belt stops. The robot will pick up the part only.

Station 6--The robot brings the part to the rotary table.

The purpose of this station is to paint the top third of the part as it rotates on the table. The program will cause the rotary table to complete two revolutions. When finished rotating, the robot will pick up the part.

As the rotary table turns, the demonstration cell simulates a spraying operation. An option at this *point would be to use an air brush to paint the part. This could be accomplished using a couple of relays.*

Station 7--The robot will deposit the finished part into a container. The robot will return next to Station 5 and pick up the carrier. The robot will return the carrier to Station 2 and then wait for instructions to pick up another part from the lathe's chuck.

SCORBOT COMMANDS FOR SENSOR ACTIVITY

S/M #	Command #	Command Statement
	1	Remark: If input #1 on, start the work cell
	2	Remark: 2
	3	Remark: 3
	4	Remark: 4
	5	Remark: 5
	6	Remark: 6
	7	In input #2 on, jump to 9
1	8	Jump to line #7
	9	Go position 1 *fast
	10	Go position 2 *fast
	11	Wait 1 second
	12	Close gripper
	13	Wait 1 second
	14	Go position 3 speed #2
	15	Go position 4 *fast
2	16	Go position 5 *fast
	17	Go position 6 speed #4
	18	Go position 7 speed #1
	19	Open gripper
	20	Go position 8 speed #5
	21	Go position 9 speed #5
	22	Go position 10 speed #5
	23	Close gripper
	24	Go position 11 speed #5
	25	Go position 12 *fast
	26	Go position 13 speed #3
	27	Go position 14 speed #4
	28	Open gripper
3	29	Go position 15 *fast
	30	Turn on output #2
	31	If input #4 on jump to 38
	32	Jump to line #31
	33	Turn off output #2
	34	Wait 1 second
	35	Turn on output #3
	36	If input #2 on jump to 38
	37	Jump to line #36
	38	Turn off output #3
	39	Wait 1 second
	40	Turn on output #2

S/M #	Command #	Command Statement
4	41	If input #3 on, jump to 41
	42	Turn off output #2
	43	Turn off output #4
	44	If input #2 on, jump to 44
	45	Turn on output #2
	46	Turn on output #4
5	47	If input #5 on, jump to 49
	48	Jump to line #47
	49	Turn off output #2
	50	Go position 16 *fast
	51	Go position 17 speed #4
	52	Close gripper
	53	Go position 18 *fast
	54	Go position 19 *fast
6	55	Go position 20 *fast
	56	Go position 21 *fast
	57	Open gripper
	58	Go position 22 speed #4
	59	Turn on output #4
	60	Go position 23 *fast
	61	Turn off output #4
	62	Go position 24 speed #3
	63	Close gripper
	64	Go position 25 speed #3
	65	Go position 26 speed #4
7	66	Go position 27 *fast
	67	Go position 28 *fast
	68	Open gripper
	69	Go position 27 *fast
	70	Go position 29 *fast
	71	Go position 30 speed #4
	72	Close gripper
	73	Go position 29 speed #5
	74	Go position 31 *fast
	75	Go position 34 speed #5
	76	Go position 32 speed #2
	77	Open gripper
	78	Go position 33 *fast
	79	Jump to line #1

PROCEDURE 2: Technical Development of an Automated System Based on the Demonstration Model

During the technical portion of this activity, the class as a whole will decide upon an automated cell to be constructed using sensors. The class will then break up into teams, with each team being responsible for a portion of the cell's actual construction and programming. The individual parts of the technical activity developed in this packet parallel the demonstration activity. The cells developed by the class need to use the sensors from the demonstration if you are going to use the physics from this activity. However, the class is not limited to just those sensors or the way those sensors were used in the demonstration. By allowing for individual input in the design and construction of the cell, the activity will be more exciting and beneficial to those involved.

Part A - Developing an Automated Cell

Using the demonstrated automated cell as a model, the class as a whole will develop an automated cell similar to the demonstration model. The class should use all of the sensors used in the demonstration but is not limited to just those sensors. After the cell and its activities have been agreed upon by the class, the class will be divided into teams with each team developing a different part of the cell or its activity.

TIME FRAME: One 50-minute period

OUTLINE: I. Development of the Idea

A. The class will be given enough time to brainstorm as to what they will make in their automated system and what activities the system will use.

B. Once the ideas have been expressed, the group must narrow them down to decide upon a product and a plan of action.

C. Details need to be added as to which things will be done and in which order.

II. Division into Teams

A. Now that the parts and activities of the system have been developed, the class must be divided into teams to handle the development and programming of the system.

1. The number of teams is determined by the number of system components and activities.

2. Each team should be assigned a task which takes approximately the same amount of time to complete.

ANTICIPATED PROBLEMS:

Brainstorming with a large group can be difficult--plan strategies to keep students on task.

The equal time distribution is critical to the successful completion of the cell. If time cannot be divided equally, then non-class time will need to be spent on those activities requiring more time than the average.

METHODS OF EVALUATION:

Observation during the process

Part B - Programming a CNC Lathe to Produce a Part To Be Used in the Automated Work Cell

During this part of the activity, students will be able to run a simple program to cut a part using a CNC Lathe. Following an example in the student guide, teams will have an opportunity to create a program file on the computer, verify the program, save the program, mount the work piece in the lathe, test run the program, and finally, run the actual program on the lathe.

MATERIALS, EQUIPMENT, APPARATUS:

SpectraLIGHT lathe
SpectraLIGHT software
Graphics Aided parts programming software
Apple IIe or Apple IIGS
SpectraLIGHT CNC Lathe System Training Guide
  Student Manual (copyright 1986)

TIME FRAME: Two 50-minute periods

OUTLINE:

I. Having seen the demonstration on how to program and produce a part using the lathe, the students will follow the procedure in the SpectraLIGHT Student Manual starting on page 7-2, sample program #1, Plug Gauge.

   a. Steps 1-12 may be completed as a class activity using the computer lab.

   b. In steps 13-23, each group of students will have to take turns on the lathe to test their programs.

ANTICIPATED PROBLEMS: Having too few computers and/or lathes will cause a backup which must be planned for in advance.

METHODS OF EVALUATION:

Printouts of program
Observation of a dry run
Final product generation

REFERENCES, RESOURCES, VENDORS:

Light Machines Corporation
669 East Industrial Drive
Manchester, NH 03103
(603) 625-8600

Energy Concepts, Inc.
7440 North Long Avenue
Skokie, IL 60077
(708) 283-4422

Aidex Corporation
1802 N. Division St.
Morris, IL 60450
(800) 251-9935

Part C - Creating a Carrier and Base

Using equipment in the Tech lab, students will create their own part carrier and base. During this part of the activity, a team of students will have an opportunity to use tools and machines commonly found in a Tech lab to produce a part carrier and a base for the carrier. A drawing of the demonstration carrier and base are shown in Figure G-12-1 ("Parts Carrier") and Figure G-12-2 ("Parts Carrier Base"). This is just an example. The team may create its own design to fit the manufactured part.

MATERIALS, EQUIPMENT, APPARATUS:

Metals lab equipment as needed
Drafting tools
Soldering equipment
Thermistors
Wire (22 gauge)
Calibrated rheostat

TIME FRAME: One and one-half 50-minute periods

OUTLINE:

I. The team of students will be given a block of time to brainstorm and draw detailed drawings of their carrier and base.

Note: The carrier must have a place for the thermistor and wires to be inserted into the portion of the turned part to be heated and later cooled.

II. After the drawing of the carrier and base has been turned in for inspection, the team will then go to the Metals lab for the construction of the carrier and base.

Note: Keep the carrier and base simple. Accuracy in construction is important. If either becomes too complex, accuracy will be sacrificed. It will also take too much time in construction.

III. Once the base and carrier are complete, the thermistor may be assembled as shown in Figure G-12-3 ("Thermistor Wiring Diagram").

Note: Be sure to leave enough wire attached so that the robot can take the carrier with the thermistor from its base, place it on the conveyor belt, and allow it to run the length of the conveyor belt.

IV. After the carrier assembly and base have been completed, fasten the base on the cell as agreed upon in Technology activity, Part A.

ANTICIPATED PROBLEMS: The ability of the group in the Metals lab will determine the complexity of base and carrier to be made.

METHODS OF EVALUATION:
Observation during activity
Participation during activity
Final product outcome and function

Part D - Preparation and Attachment of Sensors and Lamps

Using an infrared sensor, a photoconductive cell, an infrared lamp, and an incandescent lamp, the team will make the necessary mounting and adjustment brackets, prepare the sensors for attachment, and attach the sensors and lamps to the system at loca-tions agreed upon in Part A of Procedure 2.

TIME FRAME: One and one-half 50-minute periods

OUTLINE:

I. Infrared Sensor

Assemble the photoelectric sensor to the conveyor belt and interface box as indicated in Figure G-12-4 ("Conveyor/Infrared Sensor Loca-tion") (use the bracket supplied with the sensor).

II. Photoelectric Cell (CdS Cell)

   A. Mount the CdS cell in a small tube.

      1. The tube must be very close to the diameter of the cell.

      2. The cell must be square in the tube so that light entering the tube will strike the cell squarely.

      3. Connect the CdS cell as shown in Figure G-12-5 ("Conveyor/CdS Cell Location").

III. The Lamps

   A. The infrared lamp needs to be just above the sensor and parallel to the front of the sensor. It must also be aimed directly across the conveyor so that the light will strike the part in greatest concentration with very little light striking the sensor.

1. Install the lamp as shown in Figure G-12-6 ("Lamp/Infrared Sensor Location").

2. To activate the lamp using the Scorbot, a relay must be installed on the hot line of the lamp. The relay will be used to activate the lamp when the infrared sensor is activated.

   Connect the lamp and relay to interface box as shown in Figure G-12-7 ("Lamp/Relay Wiring Diagram").

B. The incandescent lamp must be aimed at the photoconductive cell. A shroud around the bulb would help direct the light at the CdS cell.

Attach the incandescent bulb as shown in Figure G-12-8 ("Lamp/CdS Cell Location").

ANTICIPATED PROBLEMS: Make sure the polarity of the lamp plug is correct; otherwise one could get a shock.

METHOD OF EVALUATION: Operation of final product

Part E - Connect Conveyor Motor/Make Rotary Table and Motor Mount

During this part of the activity, the team will connect the conveyor motor and make the rotary table and motor mount for the auxiliary motor. The above-mentioned components will then be installed in the automated system at the positions agreed upon in Part A of Procedure 2.

TIME FRAME: One and one-half 50-minute periods

Note. This group will need an extra member to complete the work on time. If there is a student in class with experience on the metal lathe, place that student in this group.

OUTLINE:

I. Cooling Fan Installation

  A. The cooling fan is wired in the circuit in a manner similar to that of the lamp. Because of the way the fan operates in the system, it needs to be connected to the normally closed side of the relay.

    1. Position the cooling fan to blow on the part as it is stopped in front of the CdS cell.

    2. Wire the fan as shown in Figure G-12-9 ("Fan/Relay Wiring Diagram").

II. The Lever Microswitch

  A. The level microswitch is used to stop the conveyor as the part reaches the end. The microswitch activates as the carrier strikes the lever arm with enough force to close the circuit which in turn causes the program to shut off the conveyor.

  B. Connect the microswitch in the system as shown in Figure G-12-10 ("Lever Microswitch Location/Wiring Diagram").

III. The Conveyor Motor

  A. The conveyor motor in this activity is operated off output 2R at the "normally open" position. This is necessary so that the motor could be operated by the sensors rather than by the computer using time to start and stop it.

  B. Connect two leads to the plug of the conveyor motor line cord. One of the wires goes to pin 1 and one of the wires goes to pin 9. See Figure G-12-11 ("Conveyor Plug Pin Wiring Diagram").

    1. The other end of the wire connected to pin goes to the interface ground.

2. The other end of the wire connected to pin 9 goes to the output terminal 2R normally open.

3. A jumper is needed from 3R common to 2R common to complete the connection of the conveyor motor to the interface.

IV. The Rotary Table and Auxiliary Motor Base

A. A rotary table may be purchased for the motor. However, the table for this activity can be made in the Metals lab using a lathe, drill press, and taps.

Construct the rotary table according to Figure G-12-12 ("Rotary Table").

B. The auxiliary motor which comes from Eshed comes unmounted without a base. In order to take advantage of the rotary table, a simple mounting bracket and base must be added.

See Figure G-12-13 ("Motor Mount") for details of the bracket and base.

C. Make the electrical connection for the motor by plugging the line cord into motor drive #6 on the interface box.

V. Power Supply

A 12 V power supply is used in this activity to power the relays on the Scorbot interface box. The power supply is wired as shown in Figure G-12-14 ("Power Supply Wiring Diagram").

METHODS OF EVALUATION: Comparison of manufactured parts to the design specifications

Observation during the activity

Operation of the developed and installed components.

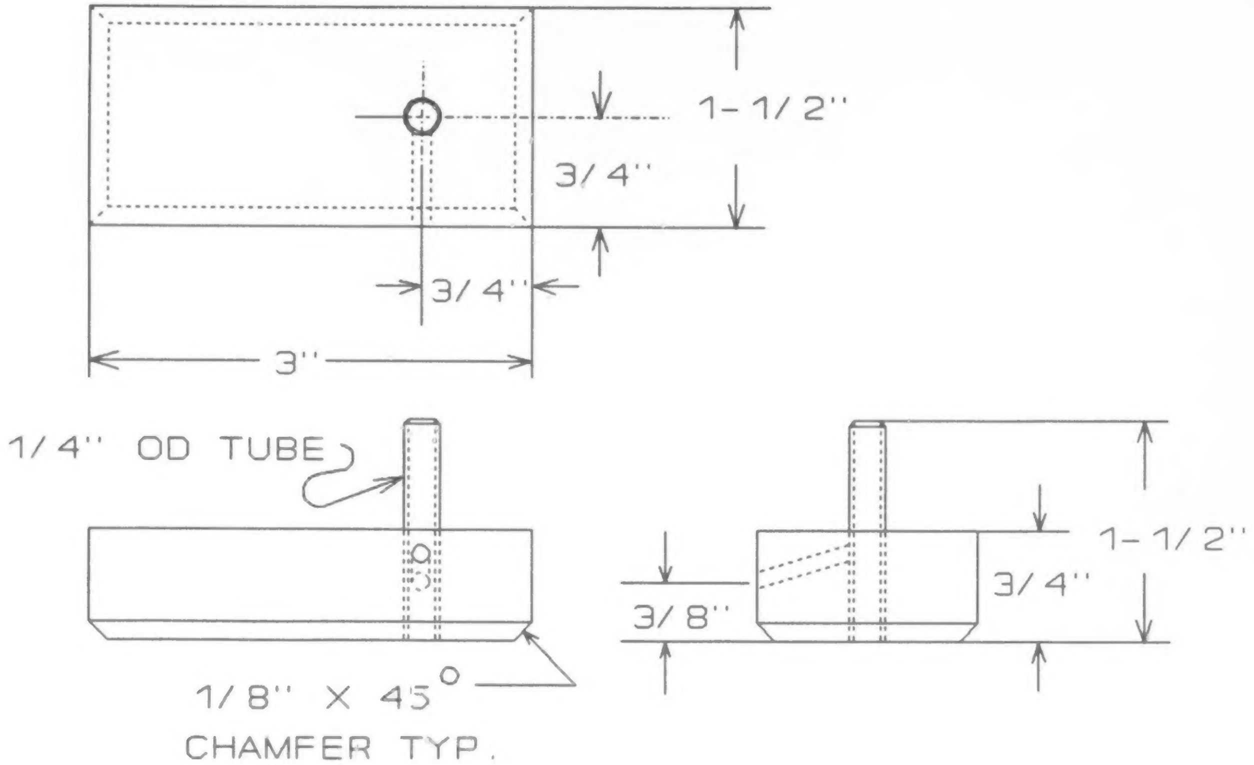

1-1/2"
3/4"
3/4"
3"
1/4" OD TUBE
1/8" X 45°
CHAMFER TYP.
1-1/2"
3/4"
3/8"

Figure G-12-1

Parts Carrier

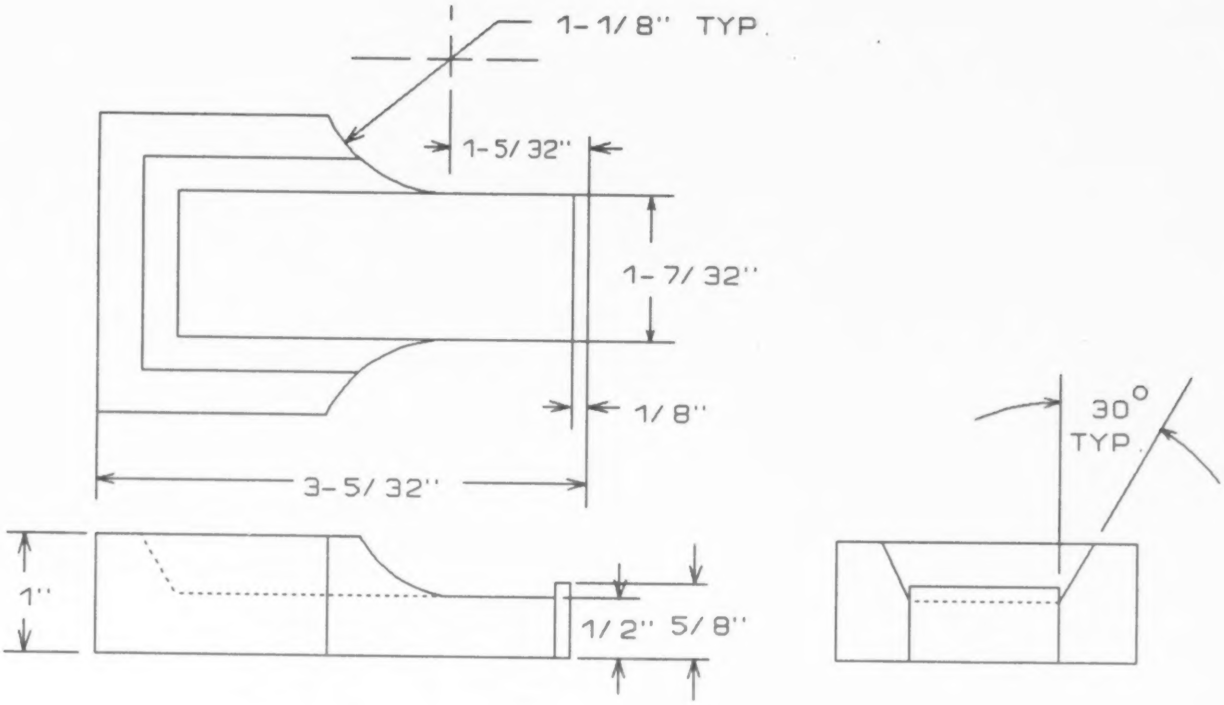

1-1/8" TYP.
1-5/32"
1-7/32"
1/8"
3-5/32"
1"
1/2"
5/8"
30° TYP.

Figure G-12-2

Parts Carrier Base

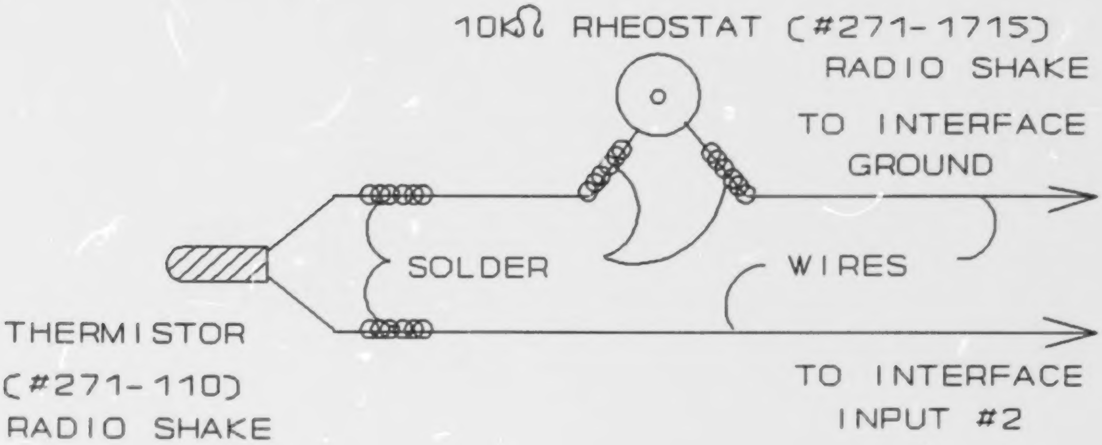

10KΩ RHEOSTAT (#271-1715)
RADIO SHAKE
TO INTERFACE
GROUND
SOLDER
WIRES
THERMISTOR
(#271-110)
RADIO SHAKE
TO INTERFACE
INPUT #2

Figure G-12-3

Thermistor Wiring Diagram

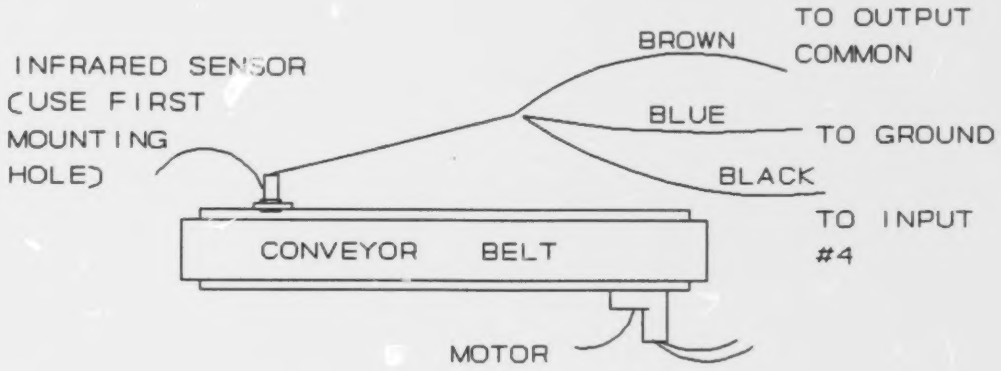

INFRARED SENSOR
(USE FIRST
MOUNTING
HOLE)
BROWN
TO OUTPUT
COMMON
BLUE
TO GROUND
BLACK
TO INPUT
#4
CONVEYOR BELT
MOTOR

Figure G-12-4

Conveyor/Infrared Sensor Location

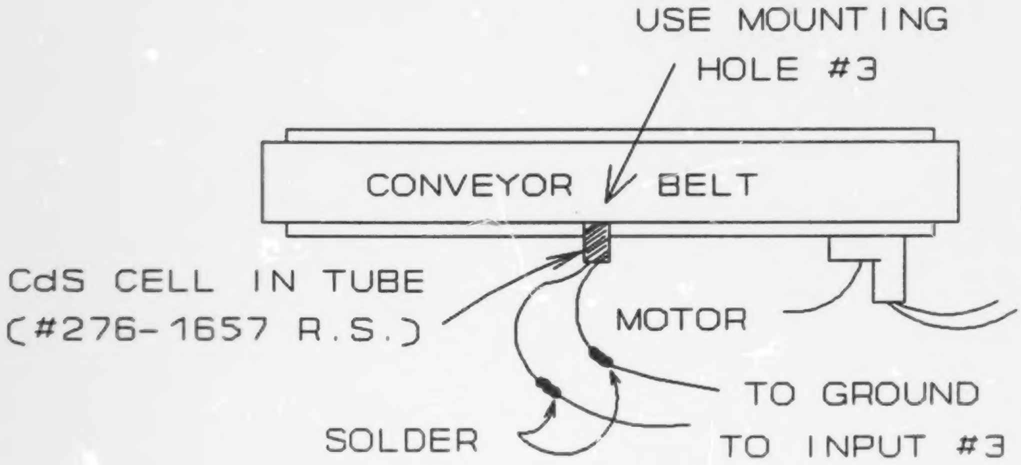

USE MOUNTING
HOLE #3
CONVEYOR BELT
CdS CELL IN TUBE
(#276-1657 R.S.)
MOTOR
TO GROUND
SOLDER
TO INPUT #3

Figure G-12-5

Conveyor/CdS Cell Location

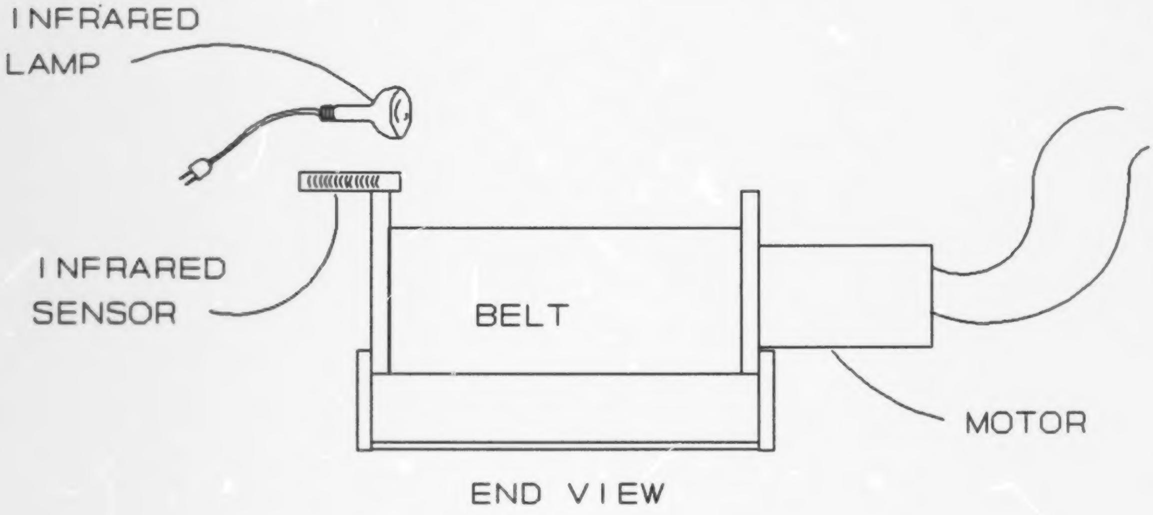

INFRARED
LAMP
INFRARED
SENSOR
BELT
MOTOR
END VIEW

Figure G-12-6

Lamp/Infrared Sensor Location

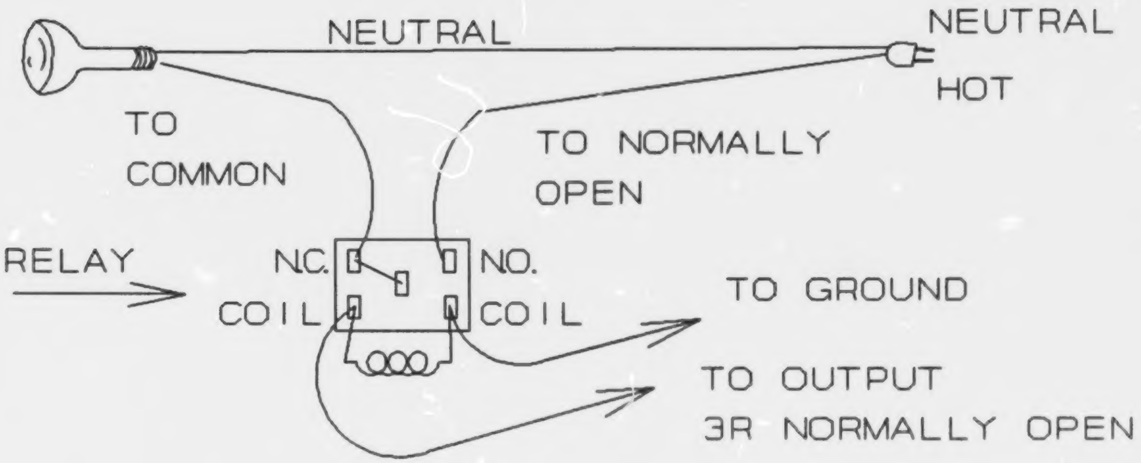

NEUTRAL
NEUTRAL
HOT
TO COMMON
TO NORMALLY OPEN
RELAY
N.C.
NO.
COIL
COIL
TO GROUND
TO OUTPUT
3R NORMALLY OPEN

Figure G-12-7

Lamp/Relay Wiring Diagram

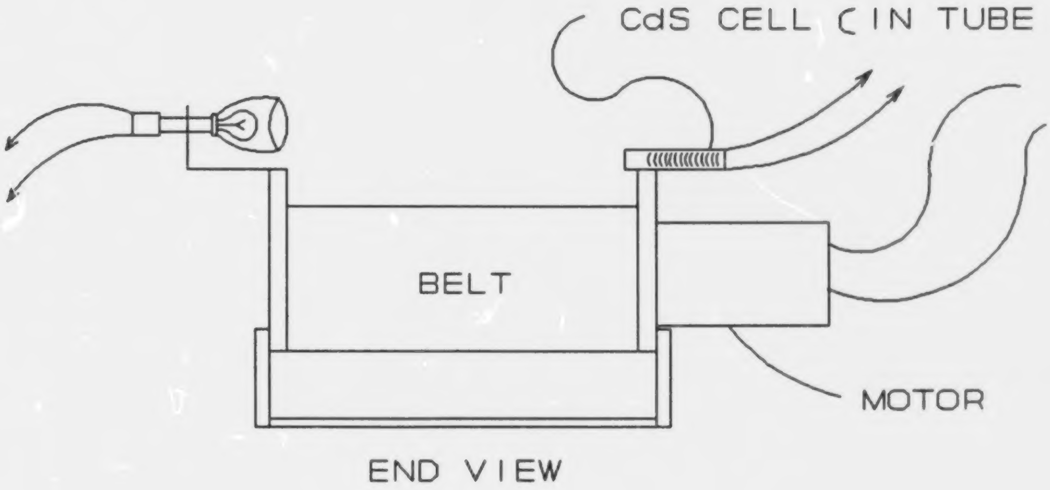

CdS CELL (IN TUBE
BELT
MOTOR
END VIEW

Figure G-12-8

Lamp/CdS Cell Location

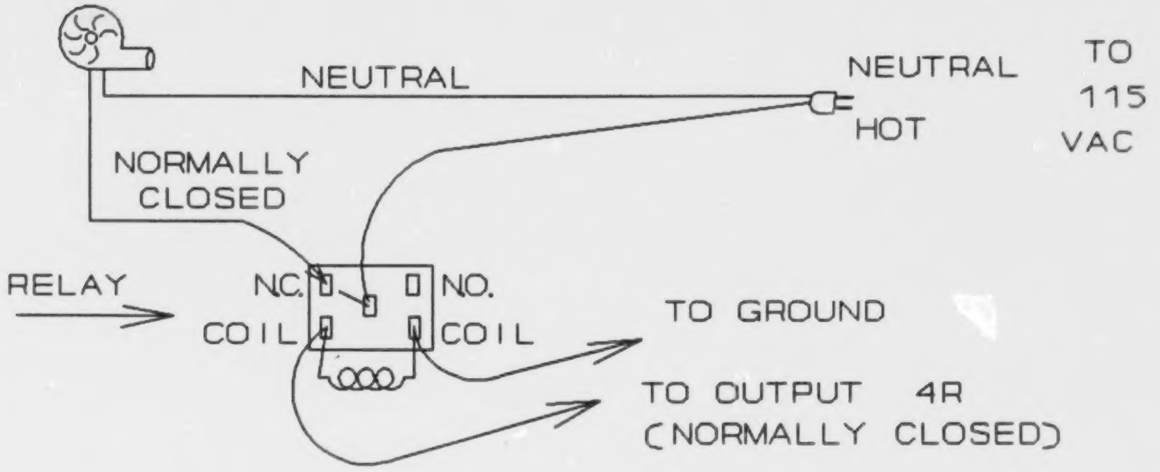
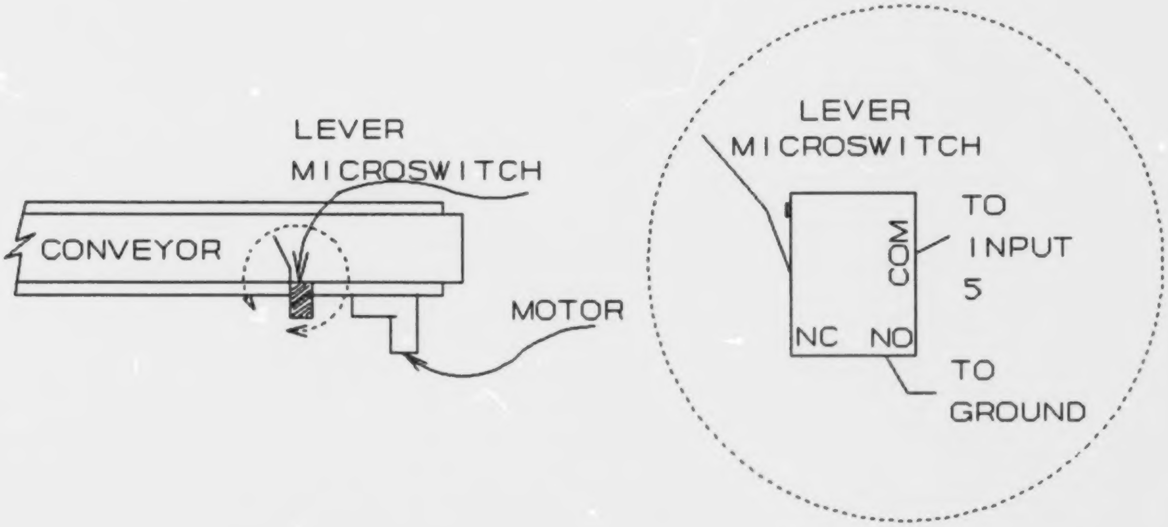

NEUTRAL
NEUTRAL
HOT
TO
115
VAC
NORMALLY
CLOSED
RELAY
N.C.
N.O.
COIL
COIL
TO GROUND
TO OUTPUT 4R
(NORMALLY CLOSED)

Figure G-12-9

Fan/Relay Wiring Diagram


a. Location

b. Wiring Diagram
LEVER
MICROSWITCH
CONVEYOR
MOTOR
LEVER
MICROSWITCH
COM
TO
INPUT
5
NC
NO
TO
GROUND

Figure G-12-10

Lever Microswitch Location/Wiring Diagram

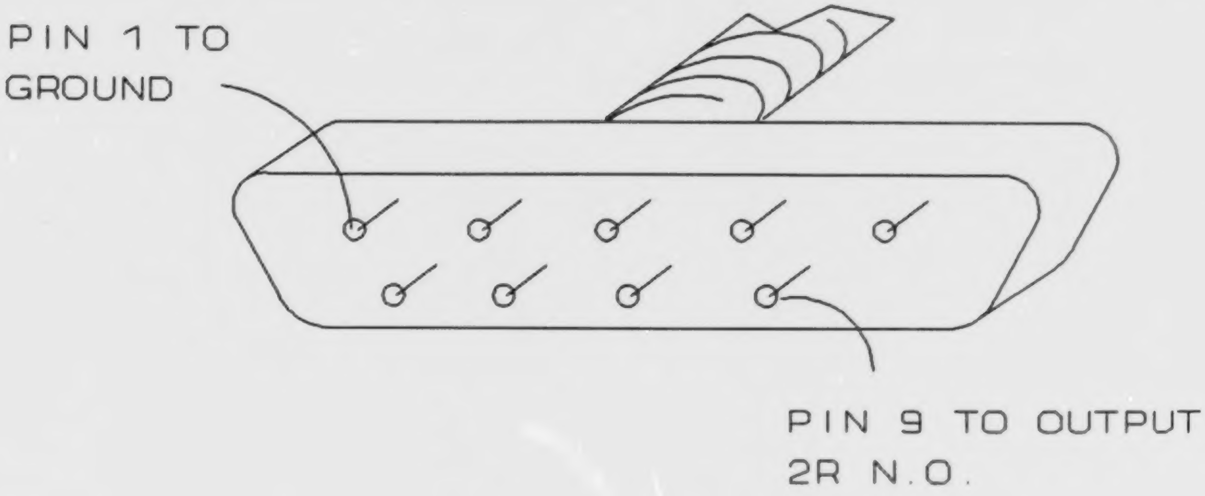

PIN 1 TO GROUND
PIN 9 TO OUTPUT 2R N.O.

Figure G-12-11

Conveyor Plug Pin Wiring Diagram

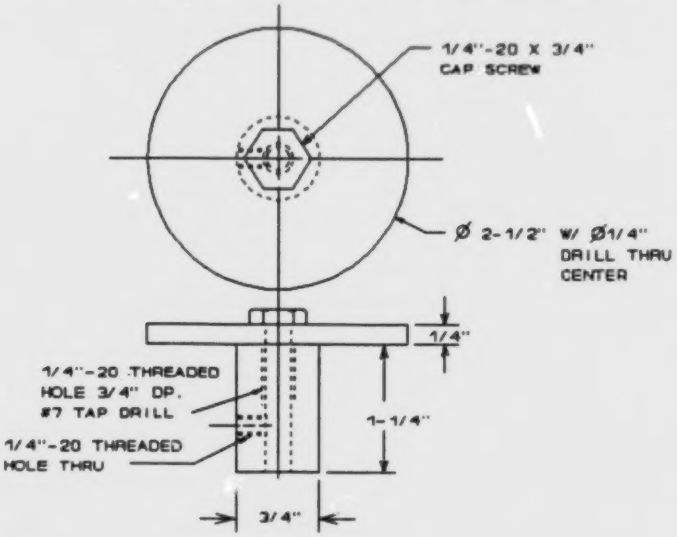

1/4"-20 X 3/4" CAP SCREW
Ø 2-1/2" W/ Ø1/4" DRILL THRU CENTER
1/4"
1/4"-20 THREADED HOLE 3/4" DP. #7 TAP DRILL
1/4"-20 THREADED HOLE THRU
1-1/4"
3/4"

Figure G-12-12

Rotary Table

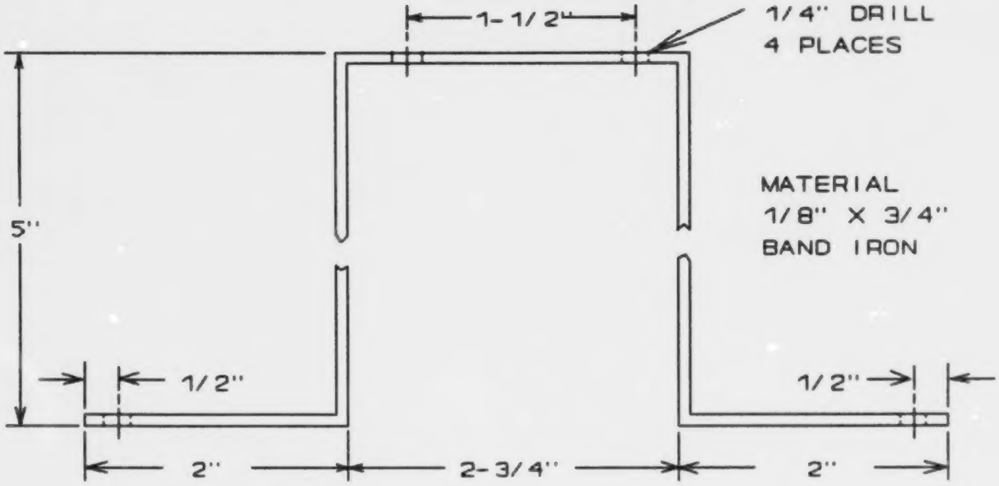

1-1/2"
1/4" DRILL
4 PLACES
MATERIAL
1/8" X 3/4"
BAND IRON
5"
1/2"
1/2"
2"
2-3/4"
2"

Figure G-12-13

Motor Mount

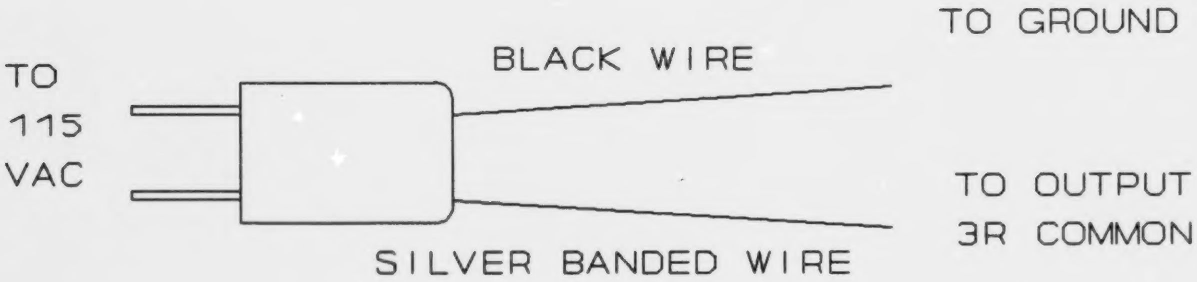

TO
115
VAC
BLACK WIRE
TO GROUND
TO OUTPUT
3R COMMON
SILVER BANDED WIRE

Figure G-12-14

Power Supply Wiring Diagram

PROCEDURE 3: Physics Concepts Applied to the System

During the Physics portion of this activity, students will be grouped by threes. Each group will take measurements at various stations in the auto- mated cell in order to perform laboratory activi-ties. At station #1, a stroboscope will be used to take frequency measurements to study rotational motion using the SpectraLIGHT CNC Lathe. At station #2, conservation of energy will be studied using the mass of the part and the height it is dropped. At station #3, the time to heat the part to temperature will be measured. Temperature, heat capacity, and resistance in a thermistor will be studied. At station #5, measurements of force and length will be used to find the torque produced by the lever arm of the microswitch. These activities are designed to use the automated system to perform measurements to be used for further graphing, calculations, and analysis of data.

Part A - Rotary Motion: Using a SpectraLIGHT CHC Lathe

A SpectraLIGHT CNC Lathe is a technological instrument used to turn metal. This lathe can be programmed to turn an aluminum rod into many different shapes and diameters. The chuck holds the metal rod in position, and as it rotates, a cutter bit is pressed against the rod. The cutter bit cuts away part of the aluminum rod creating a new shape or diameter.

The chuck and rod will be used in this activity to determine angular velocity and angular negative acceleration. The angular negative acceleration will be used to calculate the number of turns the chuck and rod make once the lathe has been turned off to the point where the chuck and rod are motionless.

CONCEPTS:	Physics:	Mathematics:
	Angular velocity	Radian measure
	Angular acceleration	Ratio and proportion
	Angular displacement	

MATERIALS, EQUIPMENT, APPARATUS: Stroboscope

Timing devices (stopwatch)

TIME FRAME: One 50-minute period

OUTLINE:

I. Angular Velocity

   A. Place a dark mark on the turned aluminum rod (this will be a reference point used in determining frequency). Use a stroboscope to measure the frequency of the rod and chuck. Record in column A of Table G-12-1 ("Angular Velocity Data").

   B. Calculate the period from frequency. Record in column B of Table G-12-1 $(T = 1/f)$.

   C. Calculate the angular velocity of the chuck. $(w_o = \theta/t)$ Record in column D of Table G-12-1.

II. Angular Acceleration

   A. Referring to the angular velocity in Section I above, record this value in column A of Table G-12-2 ("Angular Acceleration Data").

   B. With the lathe running at full speed, turn off the lathe and record the time it takes for the chuck and rod to come to a complete stop. Record in column B of Table G-12-2.

   C. Calculate the angular negative acceleration. $[\alpha = (w_f - w_o)/t;\ w_f = 0]$ Record the value in column C of Table G-12-2.

   D. Calculate the angular displacement in radians for the chuck and rod. $(\theta = W_o + .5 \alpha t_2)$. Record in column D of Table G-12-2.

   E. Calculate the angular displacement in revolution for the chuck and rod. Record the value in column E of Table G-12-2.

ANTICIPATED PROBLEMS: Use extreme caution when using the stroboscope near the lathe.

Table G-12-1

Angular Velocity Data

A	B	C	D
f (rev/s)	T (s)	O (rad)	w_o (rad/s)

Table G-12-2

Angular Acceleration Data

A	B	C	D	E
w_o (rad/s)	t (s)	α (rad/s^2)	O (rad)	O (rev)

POST-LAB QUESTIONS FOR PROCEDURE 3, PART A

1. Why is the stroboscope a useful instrument for measurement of frequency?

2. If the cutter bit were pressed against the aluminum rod as it was rotating at maximum speed and the lathe was turned off, would the number of revolutions increase or decreases as compared to the data in Table G-12-2? Explain why.

3. A hollow cylinder was placed in the chuck and allowed to rotate to maximum speed. The lathe is turned off. Will the number of revolutions of the chuck and cylinder before coming to a complete stop be the same as in Table G-12-2? Explain why.

Part B - Conservation of Energy: Part Placed on Carrier

The Scorbot is programmed to transport the turned part from the lathe to the carrier. The part will be dropped onto the carrier from a pre-programmed height. The weight of the part will be calculated and then used to calculate the gravitational potential energy. Since energy can neither be created nor destroyed, the potential energy at the start must equal the kinetic energy just as the part reaches the carrier's base. $E_p = E_k = .5\ mv^2$. Using the two equations, it is possible to calculate the velocity of the part just as it reaches the base of the carrier.

PHYSICS CONCEPTS:

- Velocity
- Force (due to gravity)
- Potential energy
- Kinetic energy

TIME FRAME: One 50-minute period.

OUTLINE:

I. Weight and Potential Energy

A. Measure the mass of the turned part with a triple beam balance or equal arm balance. Record in column A of Table G-12-3 ("Potential Energy Data").

B. Calculate the weight of the part (gravity = 9.8 m/s^2). Record in column B of Table G-12-3.

C. Measure the height the weight will fall. Record in column C of Table G-12-3.

D. Calculate the potential energy of the turned part. Record in column D of Table G-12-3. ($E_p = mg\Delta h$)

II. Conservation of Energy

A. Allow the robot to drop the part onto the carrier module.

B. The potential energy at start equals the kinetic energy at the end. Using the equation $.5\ mv^2 = mg\ h$, solve for the final velocity (v) of the part just before it hits the base of the carrier. Show the mathematics involved to solve for v.

ANTICIPATED PROBLEMS: The Scorbot must be turned off just before the part is dropped from the gripper onto the carrier module.

Make sure the mass is converted to kg and h to meters.

Table G-12-3

Potential Energy Data

A	B	C	D
mass (kg)	F_w (N)	Δh (m)	E_p (j)

POST-LAB QUESTIONS FOR PROCEDURE 3, PART B

1. Differentiate between potential energy and kinetic energy.

2. If conservation of energy holds true, what happened to the energy as it was converted into kinetic energy upon stopping on the base of the carrier module?

3. Could an object have both kinetic energy and potential energy at the same time? Explain.

4. Use dimensional analysis to show the units that make up a joule.

5. Convert 32 feet to meters.

6. Convert 5 pounds to newtons.

Part C - Temperature and Resistance: Thermistor Sensor

A thermistor is a temperature-sensitive resistor which decreases its resistance with an increase in temperature. The thermistor in this activity is used to trigger a relay switch to turn off an infrared heat lamp being used to heat up the part containing the thermistor. The conveyor belt then transports the heated part to the next station where the part will be cooled by a small fan. Once cooled, the part is then moved along to another station.

When heated, the thermistor will reach a certain temperature (to be found later in this activity) which then activates the relay to turn off the infrared lamp. The thermistor will be calibrated for resistance and temperature. Resistance will be graphed as a function of temperature and temperature will be graphed as a function of time. Actual temperature of the part will be measured over an interval of time and compared with a graph showing temperature as a function of time (combining the previous two graphs). Error analysis of the two temperature values will be calculated. Finally, the quantity of heat needed to produce a change in temperature in the aluminum part will be calculated.

CONCEPTS:

Resistance
Temperature
Specific heat
Graphing of functions
Error analysis

MATERIALS, EQUIPMENT, APPARATUS:

6 thermometers
Triple beam balance
6 timing devices
Multimeter (ohm setting)
6 cooling devices (fans)
6 heat lamps
6 thermistors
(10 KΩ +/-1% at 25°C, Radio Shack part #271-110)

TIME FRAME: Refer to each section of the outline of the procedure

OUTLINE: I. Calibration of the Thermistor

Time Frame: last 25 minutes of period over 3 days

A. Place the thermistor and turned part in a refrigerator over a 24-hour period.

B. The first day, remove the thermistor and part from the refrigerator and immediately measure the resistance of the thermistor using a multimeter.

Initial resistance = __________

C. Place the thermistor and part 1 cm from the infrared lamp. Turn on the lamp and take readings of just the resistance every 30 seconds over a 10-minute time interval. Record the resistance readings in Table G-12-4 ("Thermistor Temperature/Resistance Data").

D. At the end of the period (first day), the teacher will place a thermometer and turned part into the refrigerator.

E. On the second day, remove the thermometer and part from the refrigerator. Immediately read the temperature.

Initial temperature = __________

F. Place the thermometer inside the part. Place the part 1 cm from the infrared lamp. Turn on the lamp and measure the temperature every 30 seconds for 10 minutes. Record the temperatures in Table G-12-4, the same table used in step C for resistance readings.

G. On a separate sheet of graph paper, graph resistance as a function of temperature.

H. On a separate sheet of graph paper, graph temperature as a function of time. (This graph will be used later in this activity.)

II. Measuring the Temperature of the Thermistor

Time Frame: One 50-minute period

A. During an actual run of the automated system, have the part and carrier with the thermistor in position on the conveyor belt. Measure the elapsed time from when the heat lamp turned on to when it turned off.

Elapsed time = __________

B. Use a thermometer to measure the ambient room temperature.

Ambient temperature = __________

C. When away from the automated system, place the thermometer inside the part, making sure the part is fully cooled off. Place the part and thermometer 1 cm from the heat lamp. Turn on the lamp and leave it on for a time equal to the elapsed time recorded in step A above. Read the temperature at the end of the elapsed time.

Temperature of part = __________

D. Using the graph of temperature as a function of time in step H of Section I, draw a horizontal line through the ambient temperature (part B). At the point where the horizontal line crosses the curve in the graph, drop a vertical line to the horizontal axis of the graph. From the point located on the horizontal axis, mark off a distance equal to the elapsed time reading from step A. Remember that the part is heating up. At the end of the time interval, draw a vertical line upward until it intersects the curve in the original graph. From the point of intersection, draw a horizontal line to the vertical axis and record the temperature where the horizontal line crosses the vertical axis.

Temperature = __________

E. Compare the temperature measured with the thermometer in step C with the temperature taken from the graph in step D. Record the differences as absolute error.

Absolute error = __________°C

F. Divide the absolute error by the temperature found with the thermometer in step C and then multiply by 100%. Record this value as the relative error.

Relative error = __________%

III. Specific Heat

Time Frame: 30 minutes

A. Measure the mass of the turned part.

__________g

B. Calculate the change in temperature (ΔT) by using the ambient temperature (II-B) and the measured temperature from the heat lamp (II-C).

ΔT = __________°C

C. Use specific heat in cal/gC° from Table G-12-5 ("Specific Heat Table") for aluminum at 20° C.

Specific heat (c) = __________cal/gC°

D. Use the given equation to find the quantity of heat needed to produce a change in temperature in calories.

$Q = mc\Delta T$; Q = __________ calories

Table G-12-4

Thermistor Temperature/Resistance Data

time (min)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
resistance										
temperature										

time (min)	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
resistance										
temperature										

Table G-12-5

Specific Heat Table

---

alcohol, ethyl	0.581 (25°)
aluminum	0.214 (20°)
	0.217 (0-100°)
	0.220 (20-100°)
	0.225 (100°)
ammonia, liquid	1.047 (-60°)
liquid	1.125 (20°)
gas	0.523 (20°)
brass (40% Zn)	0.0917
copper	0.0924
glass, crown	0.161
iron	0.1075
lead	0.0305
mercury	0.0333
platinum	0.0317
silver	0.0562
tungsten	0.0322
water	1.00

POST-LAB QUESTIONS FOR PROCEDURE 3, PART C

1. What was the difference in temperature found in Section II-E of the activity? Why was a difference in temperatures founds?

2. What is a thermistor?

3. Why is a thermistor important as a sensor?

4. What is the heat capacity of a solid substance?

5. Referring to Table G-12-5, how does the specific heat of most common substances compare with the specific heat of water?

6. What does a thermometer measure? Be specific.

Part D - Torque: Microswitch on a Conveyor

A level microswitch is a mechanical sensor that either opens or closes a circuit when a lever arm is depressed. The microswitch's lever arm in the automated system is depressed by the carrier module on the conveyor belt. Depressing the lever arm causes the circuit to be closed which then stops the conveyor and signals the robot to pick up the part on the carrier. The lever arm needs a force applied to it to depress it. This produces a torque which will be calculated in this activity.

PHYSICS CONCEPTS:	Force Torque
MATERIALS, EQUIPMENT, APPARATUS:	Spring scale calibrated in newtons (should be sensitive; calibrated from 0 to 2.5 newtons) Metric ruler
TIME FRAME:	One 50-minute period

OUTLINE:

I. Torque

A. Bend the level very carefully so it bends out toward the direction of the carrier coming down the conveyor belt. (See Figure G-12-15, "Module/Lever Arm Position.")

B. Use a spring scale to measure the force required to move the carrier module with the turned part on it. Do this by attaching the spring scale to the module in the direction opposite of the moving conveyor belt. (See Figure G-12-16, "Module/Spring Scale Position.")

Keep the carrier module motionless even though the conveyor belt is moving in the opposite direction. Record the force.

Force = __________N

C. Allow for the carrier module to hit the lever of the microswitch. Visually note where the module first touches the lever arm. Measure from that point to the fulcrum point.

Distance = __________m

D. Calculate the torque applied to the lever arm of the microswitch.

T = F x d; T = __________N-m

ANTICIPATED PROBLEMS: The spring scale must be calibrated low enough to get a reading of the force. In Procedure 3, Part C (Thermistor), a temperature measurement error should be anticipated because the part sets on a metal tube which absorbs some of the heat. The metal tube is not figured in during the testing.

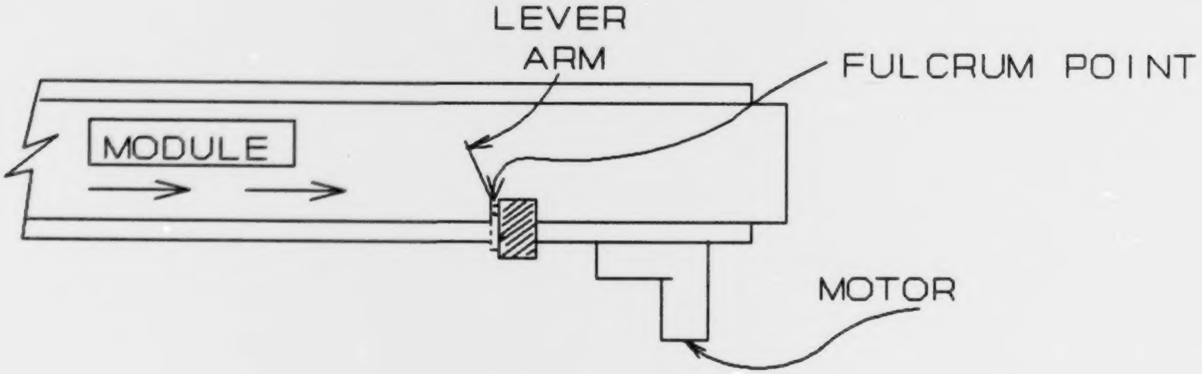

LEVER
ARM
FULCRUM POINT
MODULE
MOTOR

Figure G-12-15

Module/Lever Arm Position

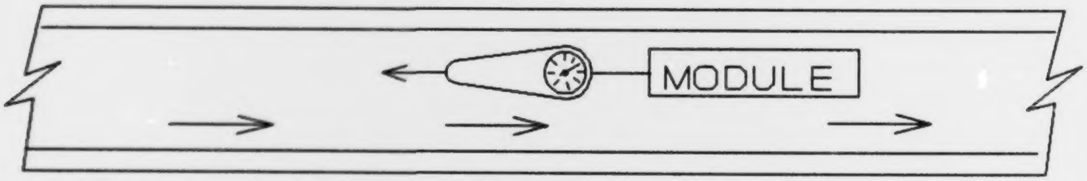


Figure G-12-16

Module/Spring Scale Position

POST-LAB QUESTIONS FOR PROCEDURE 3, PART D

1. Give two examples of where a microswitch lever arm is used in industry.

2. Explain how two persons of unequal weight can be made to balance on a seesaw (playground balance beam).

3. Would speeding up the conveyor belt cause the carrier module to hit the microswitch lever arm with a greater force? Explain your response.

4. Why was the microswitch lever arm bent outward toward the carrier module?

SENSORS MATHEMATICS WORKSHEET

The angular velocity **w** is a measure of the rate at which the object rotates. The units of angular velocity are degrees, radians, or revolutions, per unit time.

For any point on the rotating body, the linear displacement per unit time along the circular path is called the linear speed. The linear speed is zero for a point at the center of rotation and is directly proportional to the distance **r** from the point to the center of rotation. If **w** is expressed in radians per unit time, the linear speed **V** is: $V = wr$.

1. Find the missing values:

rev/min	rod/s	deg/s
1850	?	?
?	?	?
?	?	77.2

2. A wheel is rotating at 2450 rev/min. Find the linear speed of a point 35.0 cm from the center.

3. A belt having a speed of 885 in./min turns a 12.5 in. radius pulley. Find the angular velocity of the pulley in rev/min.

4. A capstan on a magnetic tape drive rotates at 3500 rad/min and drives the tape at a speed of 45.0 m/min. Find the diameter of the capstan in millimeters.

LIST OF ACTIVITIES

MOLINE HIGH SCHOOL

			Inclusive Page Nos.
Activity 1	Separation Systems Aspirator/Screens	Agricultural Group	201-210
Activity 2	Metered Mixture with Augers		211-222
Activity 3	Grain Moisture Tester		223-233
Activity 4	Nozzles and Spraying		234-242
Activity 5	Plow/Force		243-255
Activity 6	Soil Compaction		256-262
Activity 7	Belt Sander		263-278
Activity 8	Variable Resistance (Dimmer Switch)		279-301
Activity 9	Exercise Machines		302-314
Activity 10	Generator		315-329
Activity 11	Laser Survey		330-339
Activity 12	Power Tools		340-354
Activity 13	Ultrasound		355-364

ACTIVITY 1: SEPARATION SYSTEMS ASPIRATOR/SCREENS

TECHNOLOGICAL FRAMEWORK: When harvesting grain in agriculture, the chaff and impurities must be removed from the rest of the grain. This is initially done inside the combine using fans and screens for separation of these unwanted materials.

PURPOSE: To observe the use of air flow and screening as a method of separating materials

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--pumps

Mathematics--percentages

Technology--industrial and agricultural separation

PRE-REQUISITES: None

MATERIALS, EQUIPMENT, APPARATUS:

1 - aspirator (assembly instructions follow the activity)
1 - framed screen (1/4" mesh)
1 - 1-qt. freezer box
1 - tray (to place under the auger and screen)
1 - balance
1/2-1 lb. shelled corn
1 - cheesecloth bag to fit over 3" opening

TIME FRAME: 30 minutes

TEACHING STRATEGIES:

Physics teacher will discuss the operation of the apparatus.

Technology teacher will facilitate the lab.

Mathematics teacher will aid in the calculation of percentages.

TEACHING METHODOLOGY:

Discuss the operation of pumps to sustain fluid flow through the maintenance of pressure gradients.

Lab orientation/demonstration

Lab activity

Post-lab session

FURTHER FIELDS OF INVESTIGATION:

Seed corn companies use gravity machines which incorporate air, vibration, and a slanted bed to separate large from small kernels. They also make use of dust removal systems to clean kernels before processing.

Grain processing companies also use aspirators in the handling of their product to minimize the danger of dust particles suspended in the air.

Some large wood mills used aspirator systems to separate byproducts for further use.

PROCEDURE:

In agriculture, separation systems are used for purposes such as removing chaff and other types of waste from grain before taking it to market or for sorting seed into different sizes for use in planters.

In this activity, you will be testing to see how an aspirator/screen assembly separates chaff and small particulate from shelled corn.

1. Obtain a sample of shelled corn from your instructor.

2. Find the mass of the freezer container.

   mass of container = __________ grams

3. Fill the container with grain; weigh it and subtract the mass of the container to find the mass of the sample.

   mass of sample = __________ grams

4. Find the masses of the cheesecloth bag, screen, and tray. Record these masses in Table M-1-1, "Separation Aspirator."

5. With the apparatus set up as shown in Figure M-1-1, "Aspirator Setup," turn on the fan and gently pour the sample into the side opening near the top of the aspirator.

6. Gently tap the frame of the screen and then remove the filter, screen, and tray from the assembly.

7. Reweigh the filter, screen, and tray. Subtract to find the mass of the "product" in each receptacle.

8. Calculate the percentage of the original sample found in each receptacle as follows:

   % caught by the filter =

$$\frac{\text{mass of "product" in filter}}{\text{mass of original sample}}$$

9. Make observations of the differences between the products in each receptacle.

Table M-1-1

Separation Aspirator

Receptacle	Initial Mass (grams)	Final Mass (grams)	Product Mass (grams)	%	Observations
cloth filter					
screen					
tray					

ANTICIPATED PROBLEMS:

If the grain sample is too "clean," there might not be much to measure. Make then a mixture of "shelled" and "cracked" corn.

METHODS OF EVALUATION:

Observation during the lab activity

Post-lab discussion

FOLLOW-UP ACTIVITIES:

View the "Pioneer Seed Story"

Visit a grain processing company

REFERENCES, RESOURCES, VENDORS:

Pioneer Hybrid
Woodhull, IL 61490
(309) 334-2835

Ralston Purina Company
325 S. Pine St.
Davenport, IA 52801
(319) 323-3353

John Deere Harvester/East Moline
1100 13th Avenue
East Moline, IL 61244
(309) 765-8000

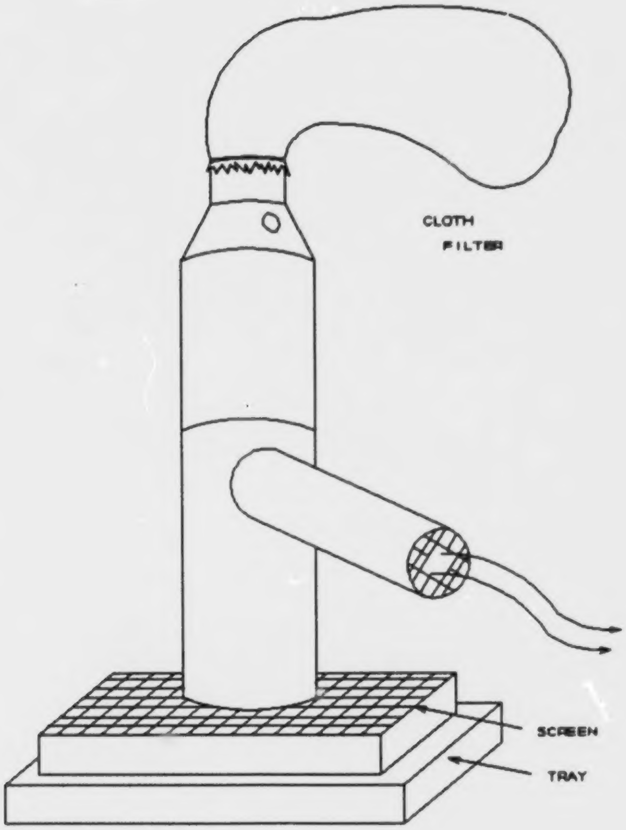

CLOTH
FILTER
SCREEN
TRAY

Figure M-1-1

Aspirator Setup

ASPIRATOR APPARATUS

Parts List

1 - 2' length of metal pipe (duct) 6" diameter
1 - 6" to 3" reducer
1 - 6" saddle (Y)
1 - 6" in-line dust fan (True Value Hardware)
24 - pop rivets
1 - 1/4" hardware cloth - 12" x 12"
1 - 4' - 2" x 2" or 1" x 2" (to make frame for hardware cloth)

Assembly

1. The saddle is held in places near one end of the 6" duct (see Figure M-1-2, "Aspirator Assembly"). Scribe on the duct where to cut out the opening for the saddle. Drill holes through the saddle and the duct for the pop rivets and fasten together.

2. Slide the reducer on the other end of the duct. Cut a 1-1/2" hole near the base of the reducer (see Figure M-1-2).

3. The duct can now be installed in the saddle. Make sure the fan doesn't protrude into the 2' duct.

4. The screen frame should be 12" x 12" (make from 1" x 2" or 2" x 2"). Staple or use a nail with a large head to fasten the screen to the frame.

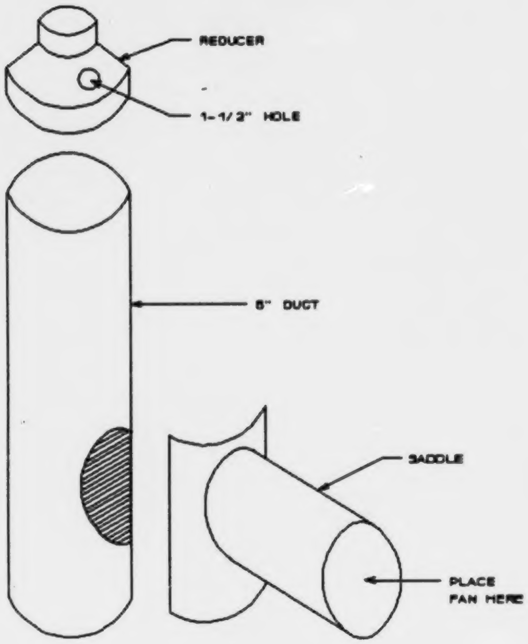

REDUCER
1-1/2" HOLE
8" DUCT
SADDLE
PLACE
FAN HERE

Figure M-1-2

Aspirator Assembly

POST-LAB QUESTIONS: SEPARATION SYSTEMS ASPIRATOR/SCREENS

1. Which receptacle caught the most product?

2. Summarize your observations of the products in each receptacle.

3. Considering the nature of the receptacles and the products, explain why the separation occurred as it did.

4. Describe situations in industry which could make use of a similar system.

MATHEMATICS WORKSHEET FOR ASPIRATOR ACTIVITY

1. Aspirators separate grain from dust and other waste material. A two-ton load of grain is aspirated and 5% of the load is lost as waste. What is the weight of the waste material?

2. Separation systems are designed for use in seed corn companies which sort grain by size and type. Seed corn is sorted to accommodate different planter styles. Size is small, medium, or large and types are round, flat, or mixed. A sample contains 25 round and 30 flat grains.

   (a) What percent of the sample is round?

   (b) What percent of the sample is flat?

3. A comparison is made between two brands of corn, Brand A and Brand B. The two brands are the same price but contain different amounts of corn. Brand A contains 10 oz. which is 2.3 oz. of water by weight. Brand B contains 12 oz. which is 3.7 oz. of water by weight.

   (a) What is the percent of corn by volume for each brand?

   (b) Which brand contains more corn for the money?

ACTIVITY 2: METERED MIXTURE WITH AUGERS

TECHNOLOGICAL FRAMEWORK: When farmers prepare feed for their livestock, they frequently use their own "recipe" mixture of various ingredients. The ingredients are usually stored separately in bins which use gravity or augers to dispense the material. In order to get the right proportions when mixing large quantities, farmers must know the rate at which the auger or gravity system delivers the feed.

PURPOSE: To study the use of augers in delivery systems.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--linear speed

Mathematics--rate

Technology--materials handling

PRE-REQUISITES: Rate

MATERIALS, EQUIPMENT, APPARATUS:

3 - auger assemblies (see assembly instructions at the end of the activity)
1 - stop watch
1 - double pan balance
1 - framed separating screen (1/8" hardware cloth)
1 - framed separating screen (1/4" hardware cloth)
3 - trays to catch the seed during separation
2 - 1-qt. freezer containers to use with the augers
1/2-1 pound each of millet, safflower and striped sunflower seed

TIME FRAME: 45 minutes

TEACHING STRATEGIES:

Students can be placed in groups of three.

Use the Technology lab or Physics lab.

Mathematics teacher will review rates.

Technology teacher will facilitate the lab.

TEACHING METHODOLOGY:

Discuss the simple machine aspects of the auger screw.

Lab orientation/demonstration.

Lab activity.

Post-lab session.

FURTHER FIELDS OF INVESTIGATION:

In addition to delivering grain to and from storage bins, augers are also used in grain dryers, combines, and grain carts.

Bread dough in a bakery is delivered from holding troughs to dough handlers through an augering system.

Besides augers, there are many other methods of material handling such as conveyor belts, air handling, gravity feed, overhead conveyor chain systems, or robotics.

PROCEDURE:

Augers are used in many phases of the farming process. Feed mixes which require different amounts of ingredients use augers and variable speed motors for mixing.

In this experiment, you will be measuring the mass flow rate of three auger assemblies, producing a grain mixture and separating the mixture to do quality control testing.

Part 1 - Calibrating the Equipment

1. Find the mass of the freezer container.

   mass of container = __________ grams

2. Fill the freezer container 3/4 full with millet.
3. Turn on the motor. Take care not to put your fingers near the auger. Pour the seed into the funnel on the auger.
4. Beginning when the grain first begins to enter the funnel, time the amount of time it takes to empty the seed from the auger. Record this time in Table M-2-1, "Auger Data."
5. Measure and record the mass of the seed.
6. Repeat steps 2-5 with motors 2 and 3, using safflower and sunflower seeds, respectively.
7. Calculate mass flow rate by the following formula:

   mass flow rate = mass/time

Part 2 - Mixing the Product

1. Using the mass flow rates from Part 1, mix a sample of bird feed in a ratio of 3-2-1, using millet, safflower, and striped sunflower, respectively.
2. Determine how many grams of each seed you want in the final product.

3. Calculate how long each auger must run to deliver the desired amount of product.

    mass flow rate (g/s) x run time(s) = desired mass (g)

    or:

    run time(s) = desired mass (g)/mass flow rate (g/s)

4. Operate each auger for its respective "run time" to create the mix.

Part 3 - Testing for Quality Control

1. Separate the mixture using the screens.

2. Find the mass of each seed sample:

    millet = ___________ grams
    safflower = ___________ grams
    sunflower = ___________ grams

3. Compare the final mass ratios to the original formula requirements.

Table M-2-1

Auger Data

Motor #/ Seed	Time (sec.)	Mass of Grain (grams)	Mass Flow Rate (g/sec)	Desired Sample Mass (grams)	Run Time (sec.)
#1/millet					
#2/safflower					
#3/sunflower					

ANTICIPATED PROBLEMS:

Caution should be exercised with auger blades which are driven by gear motors.

METHODS OF EVALUATION:

Observation during the lab activity

Post-lab write-up

FOLLOW-UP ACTIVITIES:

Visit a local farmer to view first hand the use of augers in farming.

Take a tour of a bakery which produces a large volume of goods to observe materials handling.

REFERENCES, RESOURCES, VENDORS:

W. W. Grainger Co.
333 Knightsbridge Pkwy.
Lincoln, IL 60069

True Value Hardware
2842 16th Street
Moline, IL 61265
(309) 764-5689

Continental Baking Co.
1034 East River Drive
Davenport, IA 52801
(319) 323-3647

John Deere Harvestor/East Moline
1100 13th Avenue
East Moline, IL 61244
(309) 765-8000

Schneckloth Farms
21559 LeClaire Road
Eldridge, IA 52748 or: local farm or co-op

Cope Plastics
8110 42nd Street West
Rock Island, IL 61201
(309) 787-4465

AUGER APPARATUS

Parts List

3 - AC motors from the range of 6, 12, 20, or 30 rpm. Each must have a different rpm. Available from Grainger General Catalog; Dayton model numbers 22806, 22807, 22808, or 22809.

3 - Coupling and spiders. Grainger General Catalog; 2 coupling bodies for each setup. Order the size bore to fit your motor and auger shaft: 1/4" shaft body 4X236, 5/16" shaft 1A417. Spider coupling 1X409.

1 - 3-foot length of 1-1/4" clear plastic pipe (cut to 1' lengths). Available from Cope Plastics.

6 - 90-degree elbows, Schedule 40 PVC 1-1/4" x 1-1/4".

3 - 1-1/4" tree or earth augers (Johnson Industrial Supply Co.). Available from True Value Hardware Stores.

3 - 8" plastic funnels

6 - 1/4" x 20 nuts

9 - 1/4" flat washers

1 - 3/4 x 8" x 16" plywood (base)

1 - 2" x 4" x 13" (tube support)

1 - tube silicone adhesive

Assembly

1. Cut the plywood or wood base 3/4" x 8" x 16".

2. Cut the 2" x 4" x 13" as shown in Figure M-2-1, "Auger Support." Drill or cut holes for the auger tube to fit in. Center the auger supports on the base and screw them to the base. The rear support is about 1-1/2" from the front support.

3. The earth auger has a flat spot on the end of the shaft. Cut this flat spot off and use a 1/4" x 20 die to thread this end.

4. The elbows both need a 1/4" hole drilled in them at the center of one end to allow the auger to go through as shown in Figure M-2-2, "Auger Assembly." The auger is placed in the 1-1/4" tube and a flat washer is put over the shaft at each end as a guard between the auger and the elbow. The elbows are then slid into place. The end of the shaft with threads should have two nuts placed on it. Make sure before gluing the elbows that the auger can turn easily and that the elbows are 180 degrees apart. One must point down and one up when finished. Silicone adhesive works well as you have a sizeable space to fill to hold everything together. This can also be used to hold the assembly to the supports. Let the auger tube dry overnight before handling.

5. The funnel is cut to fit over the elbow and silicone is used to glue this in place. The spider coupling and the gear motor can now be assembled to the auger. The motor should be fastened solid with a bracket made to fit your motor.

   Caution: Keep your students' fingers out of the auger with these gear motors. They have a fair amount of torque and must be treated with respect.

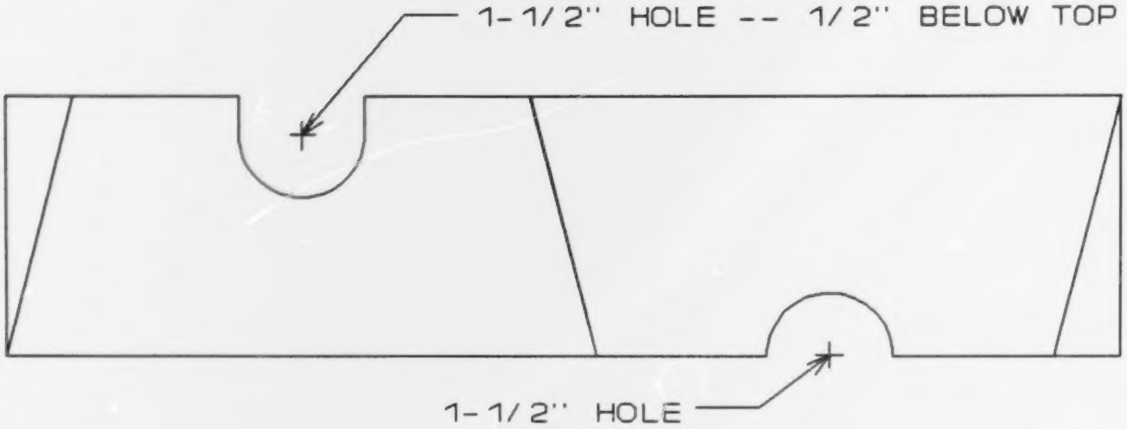

1-1/2" HOLE -- 1/2" BELOW TOP
1-1/2" HOLE

Figure M-2-1

Auger Support

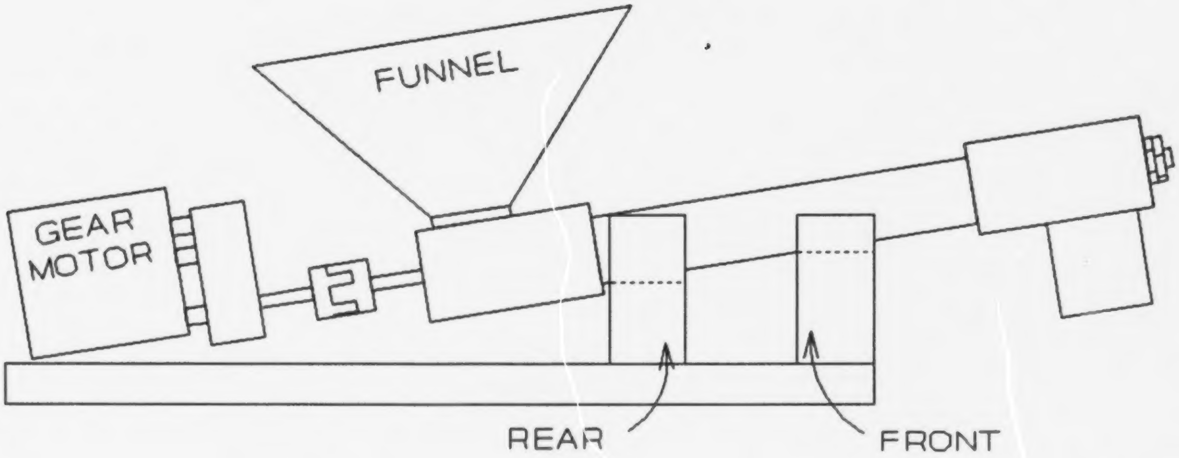

FUNNEL
GEAR MOTOR
REAR
FRONT

Figure M-2-2

Auger Assembly

POST-LAB QUESTIONS: METERED MIXTURE WITH AUGERS

1. How do the final seed masses compare to the original formula requirements?

2. Did any seed type have more difficulty than the others when passing through the auger?

3. Why would a manufacturer be concerned about formula requirements and seed damage?

4. What other products could make use of an auger delivery system?

5. What other types of delivery systems are used in industry?

METERED MIXTURE WITH AUGERS MATHEMATICS WORKSHEET

Rate in Delivery Systems

Product movement throughout factories is accomplished through different types of delivery systems. Some examples are conveyors, augers, elevators, and pipelines. The speed of the delivery system is very important in an assembly line operation where processes are interdependent.

For example, if the conveyors that move cans of cat food from the pressure cooker to the labeling machine are out of sync, there could be a backlog that would disrupt the process.

The linear rate of a delivery system is measured as a speed in distance/time: meters/sec or feet/sec.

$$\text{Rate} = \frac{\text{distance object moves}}{\text{time required for movement}}$$

1. In a certain conveyor system, a can of cat food moves 12 feet in 2.3 seconds. Find the linear rates of the conveyor.

$$\text{Rate} = \frac{12\ \text{feet}}{2.3\ \text{sec}}$$

$$\text{Rate} = 5.2\ \text{feet/sec}$$

2. After a bag of dog food has been filled, it moves 1.5 feet by conveyor to the bag closing machine. The process takes 1.2 seconds. What is the linear rate of the conveyor?

3. Find the distance traveled by a package of hamburger buns moving on a conveyor with a speed of 2.0 feet/sec for 4.8 seconds.

4. A loaf of bread moves along a conveyor toward a slicing machine at a speed of 3.5 feet/sec. How far does the bread travel in 10 seconds?

Another rate to be considered in the delivery process is production rate--the quantity of items delivered in a unit of time. Gal/min, cans/sec, liters/sec, and buns/sec are examples of production rate units.

Production rate can be calculated using the formula below:

$$\text{Production rate} = \frac{\text{quantity of item}}{\text{time required for delivery}}$$

1. In the making of hamburger buns, dough is augered from holding containers into bun-shaping machines. In 20 seconds, 3.0 lbs. of dough can move through the auger system. What is the production rate of the auger?

$$\text{Production rate} = \frac{3\ \text{lb}}{20\ \text{sec}}$$

$$\text{Production rate} = 0.15\ \text{lb/sec}$$

2. In a grain unloading system, 2.0 tons of corn are augered to a storage bin in 45 minutes. What is the production rate of this auger in lb/min? (1 ton = 2,000 lbs)

3. For a certain conveyor system, 24 cans of cat food are delivered to a packaging machine in 50 seconds. What is the production rate for this conveyor?

ACTIVITY 3: GRAIN MOISTURE TESTER

TECHNOLOGICAL FRAMEWORK: Farmers must have the proper amount of moisture in their grain before they can take it to market. Grain elevator operators do not want to pay for excess water weight nor do they want it to rot while in storage. Moisture testing takes place both in the field and at the grain elevator. If the grain is found to be too moist in field testing, the farmer either postpones the harvest or puts it through a grain drying system.

PURPOSE: To use resistance (or capacitance) to find the moisture content of grain.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--resistance

Mathematics--graphing, percents

Technology--testing moisture content, use of digital multimeters

PRE-REQUISITES: Conductivity

MATERIALS, EQUIPMENT, APPARATUS:

1 - sample testing chamber (see end of activity for suggested construction)

1 - digital multimeter (DMM)

1 - oven

1 - double pan balance

1 - 300 g samples of moist grain (red winter wheat)

1 - foil loaf pan

TIME FRAME:

90 minutes (this can be done in two class periods or spread over several days)

TEACHING STRATEGIES:

1. The activity can be performed in the Technology lab, or wherever an oven is available.
2. The entire team can assist in the performance of the lab. The Mathematics teacher can perform the post-lab by discussing the graph and moisture percent.

TEACHING METHODOLOGY:

1. Moisture testing can be done by either testing the resistance or capacitance of the grain. In this description, resistance will be used. The apparatus will be essentially testing the conductivity of the grain.
2. Place the wheat in a container. Fill the container with water and immediately drain the excess water from the grain. Let the container of grain stand overnight. (Don't fill the container too full as the grain will swell.)
3. If this activity is done as a group and pieces of data are shared, be sure to mix the grain (top to bottom) before the students obtain their sample.

4. When doing this as a class activity, have each lab group weigh and test a sample of grain. (Be sure to emphasize accuracy.) Place each sample in a labeled foil loaf pan and bake them in the oven for varying amounts of time ranging from 10-25 minutes. Have the students re-weigh and test the samples. A second baking time and testing may be necessary to assure that the grain is completely dry.

FURTHER FIELDS OF INVESTIGATION:

Moisture testing is extremely important to the farmer. Corn, for example, should be in the range of 14.5%-17.5% moist to be acceptable for storage or purchase.

Baling hay containing more than 25% moisture is an unsafe practice for the farmer. This high content can cause the bale to sweat, producing more moisture and bacteria. If undetected, the bale can undergo spontaneous combustion.

The proper amount of moisture is also needed in the preparation of silage. Silage is feed for livestock made from leftover grasses, hay, and grains. The components of the silage are chopped up and put in a bin. The moisture in the silage is needed to cause it to ferment. The fermentation process develops usable nutrients for the animals.

PROCEDURE:

Since all grains are living organisms, moisture levels must be carefully controlled so that the grain does not mold or germinate. Grain must be tested for moisture content from the beginning of the harvest season until it is processed.

In this lab, you will calibrate a moisture tester for one type of grain by drying the grain in stages. After each drying time, the grain is weighed and the resistance is measured. From the weight measurements, you will calculate percent moisture and then construct a graph of percent moisture vs. resistance.

This graph can now be used for any grain sample of the type tested. To find percent moisture, simply measure the resistance of the samples and determine moisture by reading your graph.

1. Weigh the grain testing chamber.

2. Add 300 grams of moistened grain to the moisture tester.

3. Use the DMM to measure the resistance of the grain.

4. Remove the grain from the testing chamber and place it in a foil bread pan. Be sure to remove all the grain.

5. Place the sample in a 225°F oven for 10 minutes. (Stir it occasionally.)

6. Let the sample cool. (Again, stir it occasionally.)

7. Place the sample in the chamber, weigh it, and test its resistance. Record the data in Table M-3-1, "Moisture Tester."

8. Repeat steps 4-7 until the mass of the grain no longer decreases. This will be the "Final Grain Mass."

244

9. For each trial, calculate the percent of the moisture content of the grain as follows:

$$\% \text{ moisture} = \frac{\text{trial mass} - \text{final grain mass}}{\text{trial mass}}$$

10. Graph resistance versus % moisture for the grain sample. Be sure to use a smooth curve when connecting data points.

Table M-3-1

Moisture Tester

Trial # minutes	Trial Mass (grams)	Resistance (ohms)	% Moisture
1			
2			
3			
4			
5			
6			
7			
8			

Final Grain Mass = __________ grams

ANTICIPATED PROBLEMS:	Loss of grain between trials Inaccurate measurements
METHODS OF EVALUATION:	Student graphs Answers to questions Quiz related to the activity
FOLLOW-UP ACTIVITIES:	Take moist hay or grain. Simulate a hay bale by wrapping it into a tight ball. Wrap it with some plastic wrap (allow some openings). Over a period of time, test resistivity and temperature of the bale.
REFERENCES, RESOURCES, VENDORS:	Farmex Electronic Equipment Contact person: Eric Yeager (Technical Mgr., Electronics) 130 Lena Drive Aurora, OH 44202 800-821-9542 216-562-2222 FAX: 216-562-7403

MOISTURE TESTER CHAMBER

Parts List for One Test Chamber (see Figure M-1-1, "Moisture Tester Chamber")

1 -	1-qt. plastic oil container (empty)
2 -	aluminum plates - 1/8" x 3-1/2" x 5-1/2"
2 -	#8 x 1" machine screws and nuts
4 -	#8 flat washers

Assembly

1. Cut off the tapered part of the oil container. This will leave a rectangular container with an open top about 5-1/2" tall.

2. Place the plates inside the container. Put a scrap piece of wood about 2" thick inside the container between the plates. Locate the center of the side of the container and drill a hole through the container and plates. Remove the scrap wood.

3. Place a washer on the bolt and the bolt through the plate. Slide the plate into the container and push the bolt through the hole in the side of the container. Put the flat washer and nut on the bolt and tighten them. Install the other plate. Make sure the nut is on the outside of the container to allow test equipment to be hooked to it.

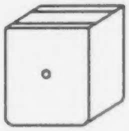


Figure M-3-1

Moisture Tester Chamber

POST-LAB QUESTIONS: GRAIN MOISTURE TESTER

1. Looking at your graph, determine the relationship between grain moisture content and resistance.

2. How would a loss of grain during the activity influence the results?

3. Why is it important for a farmer to test the moisture content of his or her crop?

4. What, if any, changes should be made in this activity if, instead of wheat, you tested another type of grain such as corn?

GRAIN MOISTURE TESTER MATHEMATICS WORKSHEET

Percents

The term "percent" means "divided by 100." For example, 40% means $\frac{40}{100}$ or 0.40.

53.6% = 0.536
2.8% = ________
123.5% = ________
0.24% = ________

To rewrite a % as a decimal, divide by 100 or multiple by 0.01.

0.98 = 98%
2.34 = ________
0.479 = ________
0.04 = ________

To rewrite a decimal as a %, multiply by 100.

A percent problem can be divided into three parts:

1. The base, B, is the entire amount.
2. The rate, R, is the percent of the base.
3. The part, P, is the portion or percentage of the base.

When each of the three quantities has been identified, the problem can be solved with the formula:

$$B \times R = P$$

Example A:

A sample of moist grains weighs 130 g. After drying for a certain time period, its weight is 86 g. What percent of the original sample was dry grain?

$G = 130$ g

$R = R$

$P = 86$ g

Note that the unknown quantity, rate, is represented simply as "R".

Label the three quantities for #1-3.

1. What is the percent efficiency of a motor, if it uses 28 units of energy and delivers 25 units of energy?

B = __________
R = __________
P = __________

2. A team played 23 games and won 65% of them. How many of the games played did they win?

B = __________
R = __________
P = __________

3. On an exam with 60 questions, a student scored 75% correct. How many questions did the student answer correctly?

B = __________
R = __________
P = __________

The following examples illustrate how to solve problems that have been correctly labeled.

Example B

What is the possible error in a 450 ohm resistor if it is marked with a silver band which indicated only 10 percent accuracy?

B = 450 ohm
R = 10%
P = P

B x R = P

(450 ohm)(0.10) = P

45 ohms = P

The possible error is (+ or -) 45 ohms of resistance.

Example C

If 14 tubes out of a lot of 150 are defective, what percent are defective?

B = 150 tubes
R = R
P = 14 tubes

B x R = P

(150 tubes) x R = 14 tubes

$$R = \frac{14}{150}$$

R = 0.09 = 9%

9% of the tubes were defective.

Complete the remaining problems using the method given in the examples.

4. If 36 feet of a 125-foot roll of wire has been used, what percent has been used?

5. A sample of grain lost 15% of its moisture. The loss was 12 g. What amount of moisture was originally present?

6. What is the percent of sales tax if an order of $25.40 has a tax of $1.91?

7. A sample of grain has a mass of 225 g. After drying, its mass is 198 g.
   - (a) What percent of the original sample was dry grain?
   - (b) What percent of the original sample was moisture?

   Note: The answers to (a) and (b) should add up to 100%.

8. How many watts of power are lost in a transformer rated at 200 watts if 3 percent of the energy is lost as heat?

ACTIVITY 4: NOZZLES AND SPRAYING

TECHNOLOGICAL FRAMEWORK:

To obtain an even application of fertilizers and herbicides on their fields, farmers must take several things into consideration, such as tractor speed, nozzle spacing, nozzle size, and the density of the liquid being used.

Fluid density varies as some chemicals are concentrated and must be diluted. These may have a water or oil base. Other chemicals are produced in a granular form and must be mixed and continually agitated while in the spray tank. Most nozzle capacity charts are based on the discharge of water. Adjustments must be made to compensate for any variation in density (or specific gravity) from that of water.

PURPOSE:

To observe the effect of density on fluid flow rate.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--density, fluid flow, specific gravity

Mathematics--rate

Technology--sprayers and flow rate

PRE-REQUISITES:

Rate
Density

MATERIALS, EQUIPMENT, APPARATUS:	Sprayer (under approximately 30# pressure) Graduated cylinder Liquid fertilizer Water Vinegar Mineral spirits Stop watch
TIME FRAME:	45 minutes
TEACHING STRATEGIES:	Group students based on number of paint sprayers Use Technology lab or Physics lab Physics teacher will cover volume flow rate and density Technology teacher will facilitate the lab
TEACHING METHODOLOGY:	Review Physics pre-requisites Lab orientation/demonstration Lab activity Post-lab session
FURTHER FIELDS OF INVESTIGATION:	Paint sprayers must also consider nozzle size for different types of jobs.

PROCEDURE:

Many fertilizers and herbicides are liquids that are applied through spraying. Correct and consistent application depends on many factors including flow rate, nozzle spacing, number of nozzles, and the speed of the tractor. One factor that is closely monitored by the farmer is nozzle flow rate.

Two factors affecting flow rate are the nozzle size and the density of the liquid to be sprayed. In this lab, you will measure the volume flow rate for different liquids and also calculate the density of each liquid. With the data from these measurements, you can make observations regarding their relationship.

1. Find the mass of the graduated cylinder.

   Mass of cylinder = __________ grams

2. Pour a few ounces of the first liquid into the jar of the sprayer.
3. Begin spraying into the graduated cylinder while your lab partner times the spraying. Collect 25-30 ml of liquid in the cylinder.
4. Measure accurately and record the volume in Table M-4-1, "Sprayer Data."
5. Find the mass of the graduated cylinder and liquid. Subtract the mass of the cylinder and record the mass of the liquid in Table M-4-1.
6. Calculate the density of the liquid according to the following formula:

   Density = Mass/Volume

7. Calculate the volume flow rate according to the following formula:

   Volume flow rate = Volume/Time

8. Repeat steps 2-7 for the remaining liquids.
9. Graph "Volume Flow Rate vs. Density" for the liquids.

Table M-4-1

Sprayer Data

Liquid	Volume (ml)	Mass of Liquid (grams)	Density of Liquid (grams/ml)	Vol. Flow Rate (ml/sec)
fertilizer #1				
fertilizer #2				
vinegar				
water				
paint thinner				

ANTICIPATED PROBLEMS:	Do not exceed the pressure capacity of the sprayer.
METHODS OF EVALUATION:	Observe students during the lab activity. Post-lab write-up.
FOLLOW-UP ACTIVITIES:	Investigate the viscosity of liquids. Perform a similar experiment except that instead of using a sprayer, use a "drip" cup (a styrofoam cup with a pin hole in it).
REFERENCES, RESOURCES, VENDORS:	W. R. Brown Co. 901 Twenty-Second St. North Chicago, IL 60064

POST-LAB QUESTIONS: NOZZLES AND SPRAYING

1. From the graph, can you determine a relationship between density and volume flow rate?

2. What factors, other than density, might influence the flow rate of a liquid?

3. Why is it important for farmers to know the applicaiton rate of a sprayer?

4. Two hundred fifty milliliters of liquid are collected from a sprayer over a period of 15 seconds. What is the volume flow rate of the sprayer?

5. A spray nozzle is listed as having a water flow rate of 12 ml/sec. How long will it take to collect a 450 ml. water sample?

6. The nozzle from question 5 is used to spray a liquid having a density of 1.1 g/ml. How will the amount of time it takes to to spray this liquid compare to the time needed for the same volume of water?

NOZZLES AND SPRAYING MATHEMATICS WORKSHEET

Choosing the Correct Nozzle

Correct sprayer dosage depends upon four controllable factors:

nozzle size
nozzle spacing
pressure
speed

Even slight variations of any of these factors can affect application rates. And although differences in application rates may be small (perhaps 1 gallon per acre), these errors become costly when multiplied by several hundred acres sprayed. Incorrect dosage can result in poor weed control or excess chemical use, either outcome being a costly alternative.

To ensure correct application rates, it is important for farmers to obtain accurate nozzle capacity readings before spraying a particular chemical solution. This can be done using conversion factors given in a table or by testing nozzle capacity in the field.

Nozzle output capacity can also be affected by the specific gravity of the mixture being sprayed. Nozzle output charts are based on discharge mixtures with the same specific gravity as water (1.00). Any change in weight per gallon of a spray mixture will affect nozzle capacity.

Table M-4-2, "Conversion Factor Table," is a conversion chart which contains multipliers to compensate for a variation in specific gravity.

Example 1

The desired application rate is 30 GPA (gallons per acre) of a chemical solution weighing 11.0 lbs. per gallon. Determine the correct nozzle size.

GPA (solution) x Conversion factor = GPA (based on water)

30 GPA (11.0 lb/gal) x 1.15 = 34.5 GPA (water)

The applicator should choose a nozzle size that will supply 34.5 GPA of water at the desired pressure.

Table M-4-2

Conversion Factor Table

Weight of Solution	Specific Gravity	Conversion Factors
7.0 lbs. per gallon	.84	.9
8.0 lbs. per gallon	.96	.98
8.34 lbs. per gallon (water)	1.00	1.00
9.0 lbs. per gallon	1.08	1.04
10.65 lbs. per gallon (28% nitrogen)	1.28	1.13
11.0 lbs. per gallon	1.32	1.15

1. From Table M-4-3, "Nozzle Chart," choose the correct nozzle needed to attain this coverage. ____________________

   Specify the pressure, speed, and nozzle spacing required for the application.

   pressure __________
   speed __________
   spacing __________

Complete the following:

2. The desired application rate is 25 GPA of 28% nitrogen solution. Determine the correct nozzle size, pressure, speed, and spacing.

3. The desired application rate is 35 GPA of a chemical solution weighing 7.0 lbs/gal. Determine the correct nozzle size, pressure, speed, and spacing.

Table M-4-3

Nozzle Chart

Nozzle Tip Size	Liquid Pressure PSI	Gallons Per Acre 20" Nozzle Spacing				Gallons Per Acre 30" Nozzle Spacing			
		5 MPH	6 MPH	7 MPH	8 MPH	5 MPH	6 MPH	7 MPH	8 MPH
1	30	42.1	33.4	28.4	25.8	28.4	23.9	20.6	18.1
	40	45.7	38.6	33.7	28.9	32.7	27.4	23.6	20.8
	50	51.3	43.4	38.1	33.2	36.4	30.5	26.3	23.1
2	30	51.9	42.9	37.6	32.6	35.3	29.6	25.5	22.4
	40	58.4	49.5	43.1	37.2	40.6	34.0	29.3	25.8
	50	64.8	55.3	48.4	42.5	45.3	37.9	32.6	28.7

PHYS-MA-TECH

AN INTEGRATED PARTNERSHIP

ACTIVITY 5: PLOW/FORCE

TECHNOLOGICAL FRAMEWORK:

In farming, there is a need to properly prepare the soil to obtain the highest yield for the farmer, while at the same time conserving the environment for future generations.

Methods of soil preparation are "no-till," "minimum-till," and "conventional" tillage. Each method has its own advantages and disadvantages relating to cost, erosion control, moisture conservation, and weed control. The choice of farming method is influenced by many factors, including soil type and terrain.

In this activity, the motion of a cultivator blade through soil will be examined.

PURPOSE:

To investigate the force required to pull a plow through soil under various conditions.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--force

Mathematics--angle measure

Technology--operation of plows

PRE-REQUISITES: None

MATERIALS, EQUIPMENT, APPARATUS:	1 - plow box (see directions for construction at the end of the activity) 1 - spring scale (50-100 lb. capacity) 1 - shovel Enough dirt to fill the wood box about 2/3 full
TIME FRAME:	60-90 minutes
TEACHING STRATEGIES:	Students can be placed in groups of three or four. Use the Technology lab or set up the unit outside.
TEACHING METHODOLOGY:	Review force concepts Lab orientation/demonstration Lab activity Post-lab session
FURTHER FIELDS OF INVESTIGATION:	In addition to farming, various types of plows are used for installing cable TV, phone lines, gas pipe, etc.

PROCEDURE:

In this lab you will test the amount of force required to pull a cultivator blade through different soil types.

You will also test the effect of compaction and moisture on the force required to pull the blade.

1. Fill the box 2/3 full with soil. Do not pack the soil while filling.
2. Position the cultivator blade so that it is parallel to and below the surface of the soil.
3. Pull the plow through the soil at a constant rate. Observe the action of the soil as the plow moves through it and record the force measured in Table M-5-1, "Plow Data."
4. Change the angle of the cultivator blade by dropping its tip deeper into the soil. Repeat step 3.
5. Compact the soil by walking through it. Repeat steps 3 and 4 for all angles.

Table M-5-1

Plow Data

Trial	Force 0°	Force 15°	Force 30°
Loose			
Compacted			
Moist			

ANTICIPATED PROBLEMS:

The size of the box is 8 feet long and 16 inches wide. Storage of the equipment may be difficult. Finding enough soil to fill the box may be difficult in some areas. It takes two large wheelbarrows of soil to fill the box.

Moistening the dirt may be time consuming.

METHODS OF EVALUATION:

Observation during lab activity
Lab write-up on the results of the activity
Selected quiz items on a unit test

FOLLOW-UP ACTIVITIES:

Use math concepts to determine the force required by a life-size cultivator.

Vary the activity by changing the type of blade.

Use different types of soil, for example, sand, clay, or peat.

Visit a farm equipment testing center.

REFERENCES RESOURCES, VENDORS:

Farm & Fleet Department Store
8535 Northwest Blvd.
Davenport, IA 52801

Trevor True Value
2842 16th Street
Moline, IL 61265
(309) 764-5689

John Deere Technical Center
3300 River Drive
Moline, IL 61265
(309) 765-3700

F. H. Phillips & H. M. Young, Jr. (1982). No Tillage Farming. Brookfield, WI: No Till Farmer, Inc.

William A. Hayes. (1982). Minimum Tillage Farming. Brookfield, WI: No Till Farmer, Inc.

PLOW APPARATUS

Parts List

1 - 2" x 4" x 8'
1 - 1' x 32" x 3/4" cca plywood
1 - 1/2" x 4' x 8' cca plywood
2 - pounds of 2" galvanized deck screws
2 - horizontal tracks from an overhead garage door
4 - wheels to match tracks
4 - brackets for wheels
2 - 48" pieces of slotted angle steel
24 - 1/4" x 1" bolts, nuts, and washers
1 - cultivator sweep
1 - 0-50 pound spring gauge
1 - small hand-powered winch with about 10' of cable
7 - cubic feet of dirt to fill the wood box about 2/3 full

Assembly

1. To assemble the plow box, start with the 1/2" x 4' x 8' plywood sheet. Use a saw to cut the sheet into 3 pieces: two pieces 12" x 96" and one piece 16" x 96" (see Figure M-5-1, "Plow Box--Plywood Dimensions.")

2. Cut lengthwise the 2" x 4" x 8' so you will have two 2" x 2" x 8's. Cut the 2" x 2"s to 94-1/2" long.

3. Use screws and fasten the 2" x 2" x 94-1/2"s to the bottom of the 16" x 96" plywood (see Figure M-5-2, "Plow Box--End View"). Make sure each 2" x 2" is centered from end to end on the base. They should be held back 3/4". This allows the 3/4" end panel to fit in.

4. The sides are now fastened with deck screws to the bottom assembly. The screws should be about 8" apart. Screw through the side panel into the 2" x 2". Cut two 3/4" plywood end pieces to fit inside the sides, 16" x 11-1/2". The ends can be fastened in place by putting the screws through the side panel right into the end or you can cut some short 2 x 2 braces to place inside the corners to screw into for added strength. (See Figure M-5-3, "Plow Box--Overall View.")

5. Mount the garage door track to the inside top edge of the plow box at one end (see Figure M-5-2).

6. Drill a hole in the 3/4" plywood end for the cable from the small hand winch. Mount the winch with 1/4" x 1" bolts and nuts.

7. The trolley assembly can be made from two 48" pieces of slotted steel angle. If you have access to a Welding lab, you can go that route also. Cut the steel angle to the following sizes: two 14-1/2" (sides), two 11-1/2" (front and rear), two 10-1/2" (center), and two 7-1/2" (plow holder). Assemble the trolley frame with 1/4" x 1" bolts and nuts (see Figure M-5-4, "Trolley Assembly"). The two 7-1/2" pieces are bolted together to form a "U" shape. The sweep (plow) is fastened to the "U" shape steel at one end. The top or other end goes through the space between the center pieces on the trolley. Wing nuts may be used here to make adjustment easier. Fasten an eye bolt to the front center of the trolley.

8. Mount the wheel brackets at each end on top of the 14-1/2" side pieces. The wheel brackets slide in and the trolley can now be placed in the track.

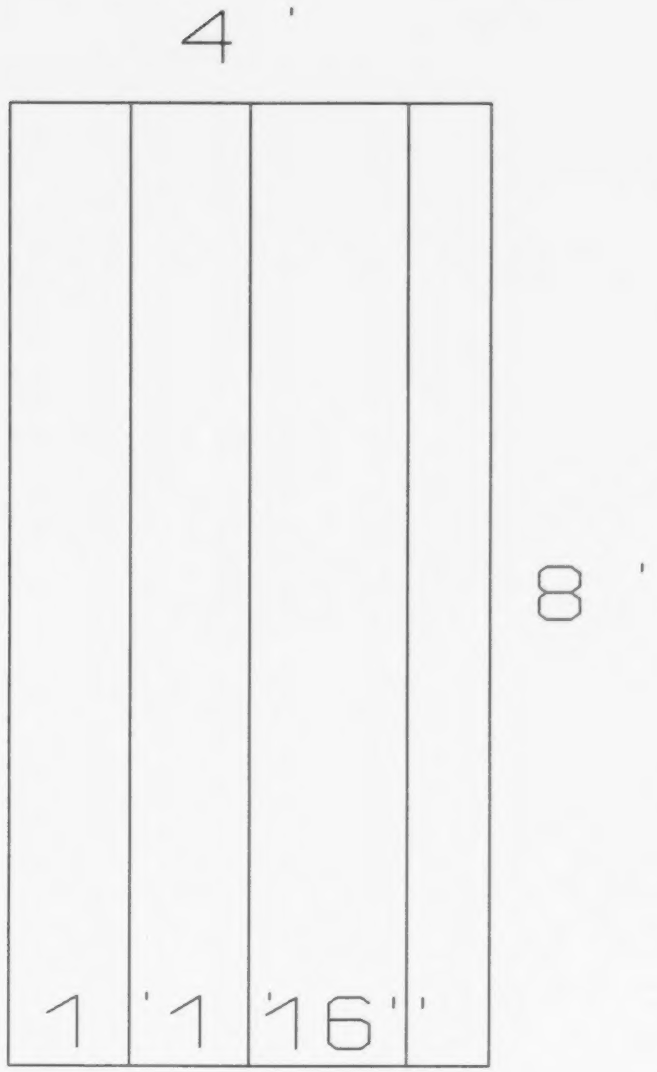


Figure M-5-1

Plow Box--Plywood Dimensions

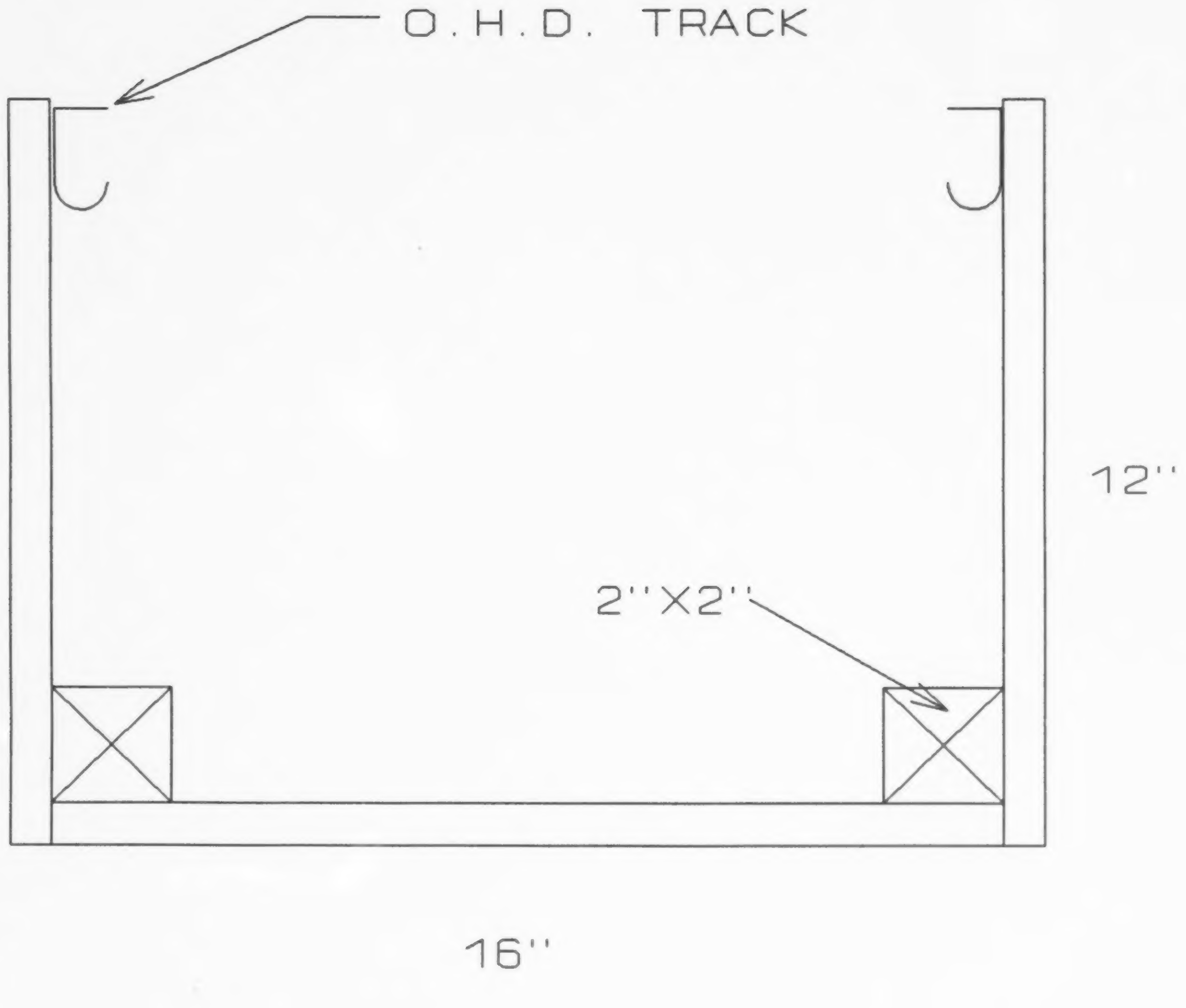

O.H.D. TRACK
12''
2''X2''
16''

Figure M-5-2

Plow Box--End View

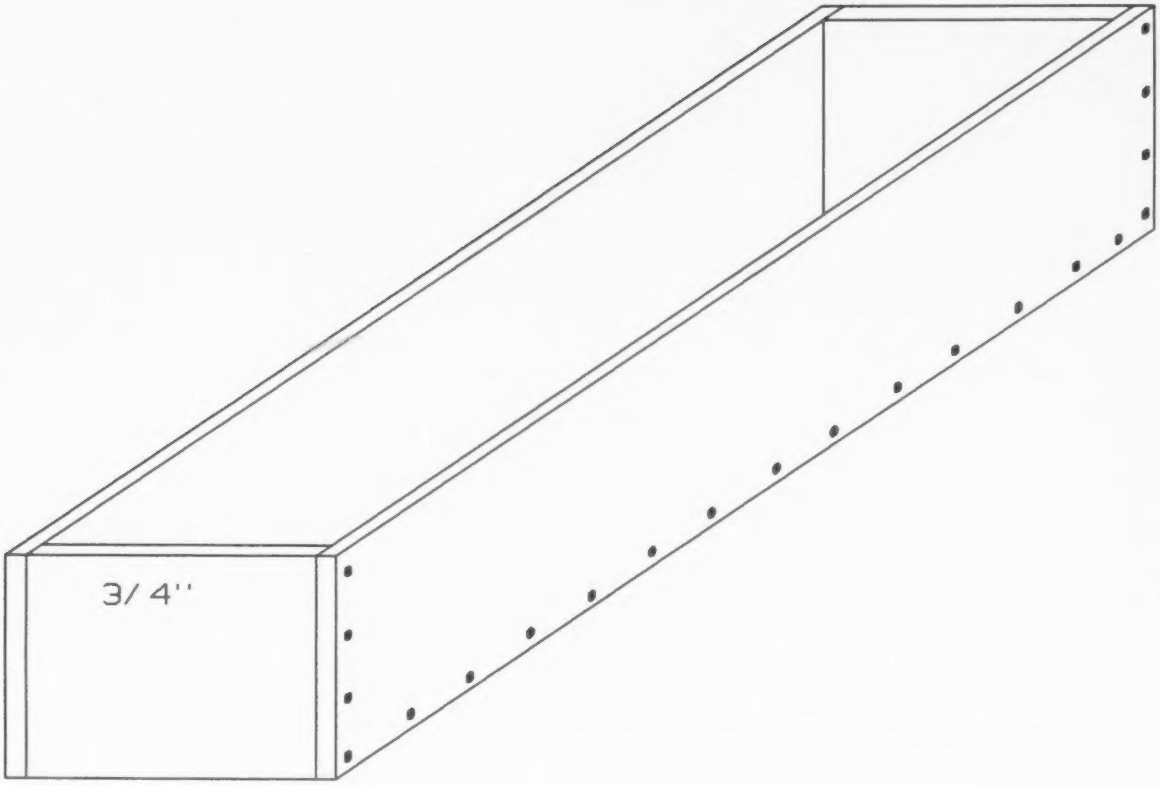


Figure M-5-3

Plow Box--Overall View

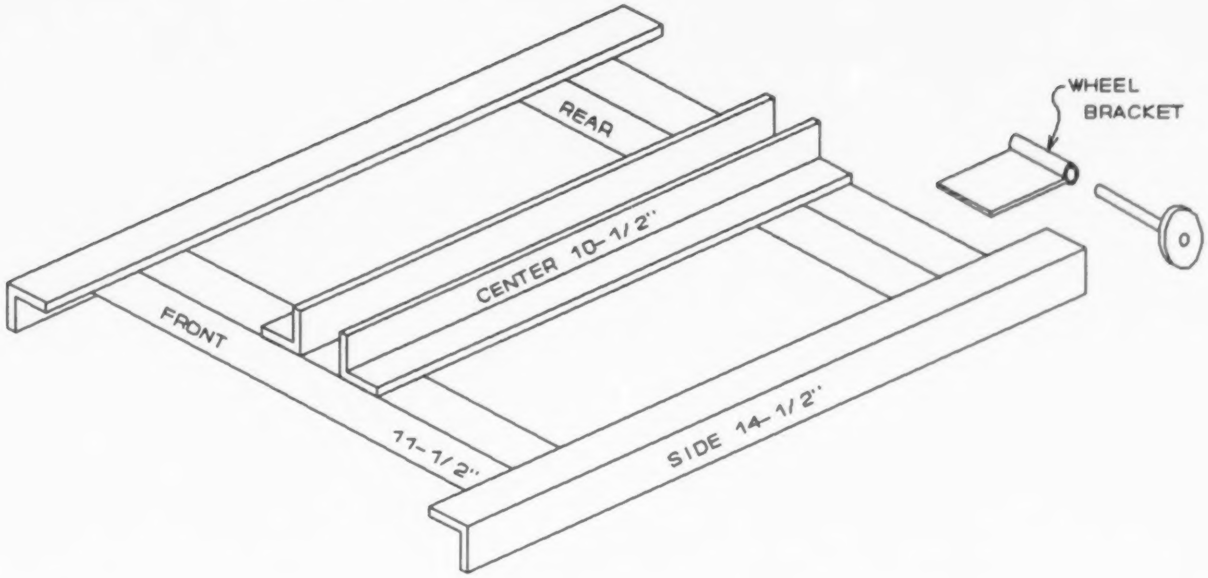

WHEEL
BRACKET
REAR
CENTER 10-1/2"
FRONT
11-1/2"
SIDE 14-1/2"
0

Figure M-5-4

Plow--Trolley Assembly

POST-LAB QUESTIONS

1. Describe what happened to the soil as the blade moved through it.

2. Did the force increase or decrease when the angle of the blade was increased? Why did this happen?

3. How would the force change if the depth of the blade was changed without changing the angle?

4. What type of soil was used in this experiment?

5. How do you think the results might change if a different soil were used?

FORCE/WORK/POWER MATHEMATICS WORKSHEET

$F = m \times a$

F = force applied (N)
m = mass of object (Kg)
a = acceleration of object (m/s^2)

1. A marble with a mass of 3.0 g has an acceleration of 2.0 m/s^2. What is the unbalanced force applied to it?

2. A golfer on a putting green exerts an unbalanced force of 8.0 N on a golf ball with a mass of 85 g. What is the acceleration of the golf ball?

$W = F \times d$

W = work (N m)
F = force (N)
d = distance (m)

$P = \frac{W}{t}$

P = power (watts)
W = work (N m)
t = time (s)

3. A person carries a 23 N sack of groceries up a 3.0 m flight of stairs.

   (a) How much work does the person do to move the groceries?

   (b) If it takes 32 seconds to climb the stairs, what power was used?

4. A hammer drives a nail 3.7 cm into a board with a force of 1.5 N.

   (a) How much work is done by the hammer?

   (b) If it takes 0.3 sec to drive the nail, what power is expended?

5. A dog uses a force of 150 N to pull a 45 Kg sled a distance of 10 m.

   (a) How much work has been done by the dog?

   (b) If the task is completed in 15 seconds, how much power was used?

ACTIVITY 6: SOIL COMPACTION

TECHNOLOGICAL FRAMEWORK: One of the problems affecting farmers' yields is that of soil compaction caused by tilling and equipment traffic. Tilling the soil breaks the physical bonds between soil particles, reduces the size and distribution of pore space, and disrupts the natural water channels created by roots. Farm equipment traffic exerts force on the soil which provides the same net effect as tillage. From 60 to 80% of the total soil compaction occurs during the first pass of farm implements across a field. This influences plant growth by affecting things such as: rainfall infiltration, root growth, runoff and erosion. The amount of damage produced by the operation of heavy machinery is determined by moisture content, texture structure, and surface cover of the soil.

In this activity, the students will be examining the effect of soil density and type on water infiltration.

PURPOSE: To study soil compaction by measuring bulk density and water infiltration rate.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--density, pressure, compression

Mathematics--rate

Technology--agricultural effects of soil compaction

PRE-REQUISITES: None

MATERIALS, EQUIPMENT, APPARATUS:

- Freezer container (1 qt.)
- dirt
- graduated cylinder
- compacting apparatus (drill press)
- vermiculite
- double pan balance
- stop watch
- ruler

TIME FRAME: 45-60 minutes

TEACHING STRATEGIES:

Physics or Technology lab

Physics or Technology teacher for presentation

Mathematics teacher assist in analysis of data

TEACHING METHODOLOGY:

Have a discussion about the effects of pressure change on materials including solids, liquids, and gasses. Include calculations of expected changes in density using tabulated compressibilities for simple homogeneous materials.

Discuss the effect of soil compaction on plant growth.

Do not have the soil too dry as the compactability will decrease.

Freezer containers do not have straight sides. Measure the width of the container at a point half way down from the top of the dirt level.

FURTHER FIELDS OF INVESTIGATION:

In the construction industry, soil compaction is desirable to increase the stability of foundations.

PROCEDURE:

The problem of soil compaction is a concern for farmers and contractors, but for different reasons. In agriculture, soil that becomes compacted inhibits plant growth. As soil becomes more dense from compaction, it restricts water, air, and root penetration. In the construction industry, soil is compacted before foundations or roadways are laid to minimize settling. The precompaction of the soil increases the stability of the structure.

In this lab, you will simulate different levels of soil compaction and measure bulk density and water infiltration rate for each level. You will observe the effects of compaction and its relationship to bulk density and infiltration rate.

1. Find the mass of the freezer container.

   Mass of container = __________ grams

2. Fill the first container to the 1-1/2 pt mark with loose soil.

3. Fill the second container to the bottom of the rim and compact it to the 1-1/2 pt mark. (After compaction, be sure to carry the container carefully so as not to break up the soil.)

4. Fill the third container to the top with loose soil and compact it to the 1-1/2 pt mark. (Take care not to burst the container.)

5. Calculate and record the volume of the dirt according to the following formula:

   Vol. = Length x Width x Depth

6. Measure the mass of the containers and dirt. Subtract the mass of the containers and record the mass of the dirt in Table M-6-1, "Soil Compaction Data."

7. Calculate the density of the dirt according to the following formula:

   Density = Mass/Volume

8. Fill a cup with 100 ml of water and pour it into the first container. Record the time it takes for the water to be absorbed into the soil.

9. After the water has reached the bottom of the soil, pour off the surface water and measure its volume.

10. Calculate the infiltration rate of the water by the following formula:

    Infiltration rate = 100 ml/time

11. Repeat the experiment using a soil mixture containing vermiculite.

Table M-6-1

Soil Compaction Data

Soil Type	Volume (cm)	Mass of Soil (grams)	Density of Soil (grams/cm)	Time (sec)	Infiltration Rate (cm/sec)
plain (loose)					
plain (med)					
plain (dense)					
mix (loose)					
mix (med)					
mix (dense)					

ANTICIPATED PROBLEMS:

Having the soil too moist or too dry could make compacting difficult.

METHODS OF EVALUATION:

Observation of students during the activity

Analysis of student data

FOLLOW-UP ACTIVITIES:

Test a variety of soil types, including those with some ground cover

Plant seeds in soil compacted to various degrees and observe the effect on root growth.

Investigate the elastic properties of aggregates.

Ask the students to predict which would weigh more: a bucket full of dry sand or the same-sized bucket full of wet sand. (Test and you will find that dry sand will weigh more.)

REFERENCES, RESOURCES, VENDORS:

Local hardware store

F. H. Phillips, & H. M. Young, Jr. (1982). No Tillage Farming. Brookfield, WI: No Till Farmer, Inc.

William A. Hayes. (1982). Minimum Tillage Farming. Brookfield, WI: No Till Farmer, Inc.

POST-LAB QUESTIONS: SOIL COMPACTION

1. How does density influence the infiltration rate of the water?

2. Compare the density of the plain soil to the density of the vermiculite mixture.

3. What factors might influence the infiltration rate of water into the soil?

4. In nature, what can happen to water which falls on soil having a low infiltration rate?

MATHEMATICS WORKSHEET FOR SOIL COMPACTION ACTIVITY

The following problems can be solved using the formula:

$$D = \frac{m}{V}$$

where: D = density
m = mass
V = volume

Common units for density include: g/cm^3, g/mL^3, lb/ft^3.

1. A bar of gold measures 6.4 cm x 2.3 cm x 2.7 cm. Gold has a density of 19.3 g/cm.

   (a) Find the volume of the bar.

   (b) Find the mass of the bar.

2. Silver has a density of 10.5 g/cm^3. Find the mass of a cube of silver whose volume is 0.04 m^3.

3. A container of soil with a volume of 120 cm^3 has a mass of 350 g. Find the density of the soil.

4. The container in the previous problem has stood for one week and lost 3% of its volume. If the change in mass is negligible, find the density.

ACTIVITY 7: BELT SANDER

TECHNOLOGICAL FRAMEWORK: Friction is a force which is undesirable when considering the inner working of machinery, but it is a very desirable force when considering surface finishing. All types of manufacturing processes produce rough-edged or rough-textured parts which need deburring. Sanding these parts may be effective if the part surfaces are large and flat.

PURPOSE: To understand how a belt sander uses friction.

To calculate the normal force of a weight on an inclined plane.

To explain the relationship between f, mu, and the normal force.

To investigate the coefficient of friction when changing angles and changing grades of paper.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--kinetic friction

Mathematics--right triangle trigonometry

Technology--surface finishing

PRE-REQUISITES: Knowledge of frictional forces including coefficient of friction and normal force

MATERIALS, EQUIPMENT, APPARATUS:	Belt sander assembly (instructions at the end of the activity) Spring scale (10-25 lb. capacity) Block to be sanded Coarse and fine sand paper
TIME FRAME:	45 minutes
TEACHING STRATEGIES:	Physics or Technology lab Physics or Technology teacher to give presentation Mathematics teacher to review present triangle trigonometry
TEACHING METHODOLOGY:	Discussion of measuring frictional forces on horizontal surface and inclined plane Discussion of lab setup and operation Lab activity Post-lab discussion of results
FURTHER FIELDS OF INVESTIGATION:	Other methods of surface finishing such as shot peening or vibratory finishing are also used.

PROCEDURE:

Friction can be a positive or a negative factor in machinery. A motor must overcome friction to operate, while a belt sander uses friction to create a smooth surface.

In this lab, you'll measure the force applied by a belt sander to a wood surface to determine the coefficient of friction. You'll see how changing the angle of the belt sander affects the force applied and the coefficient of friction. To determine the normal force when the plane is at an angle, you will use right triangle trigonometry.

You will determine the coefficient of friction by drawing a graph that models the data from your measurements. The slope of this line should be the coefficient of friction.

1. Place a fine grade of sandpaper (120) on the sander.
2. Weigh the belt sander and record.
3. Place the sander in the brace and attach the spring scale to the ramp and sanding board. Follow the setup shown in Figure M-7-1, "Belt Sander Setup."
4. Using the weight of the sander and right triangle trigonometry, compute the normal force and record the results in Table M-7-1, "Belt Sander Data--120 Grade." (Use: wt. of sander x cos θ = N)
5. With plane set at the horizontal level, turn on sander and record the frictional force reading from the scale.
6. Adjust the plane angle to first setting (10 degrees), turn on the sander, and record the frictional force.
7. Repeat for each angle, 20, 30, and 40 degrees.
8. Change the belt on the sander to a more coarse grade of paper (60).

9. Repeat steps 2-7 above, recording all values in Table M-7-2, "Belt Sander Data--60 Grade."

10. For each data table, graph f vs. N. (the frictional force vs. the normal force).

11. Compute the slope of each graph. The slope is the coefficient of friction for the sander and the board.

    Note: The parallel components of the weight of the board and the sander are important but, because of the design of the apparatus, their effects are negligible.

POST-LAB QUESTIONS: BELT SANDER

1. What is friction?

2. List several examples of situations where friction is desirable.

3. List examples of undesirable friction.

4. Describe the relationship between frictional force and normal force.

5. In this experiment, how does the coefficient of friction for the coarse sandpaper compare to that of the fine sandpaper?

6. What factors could influence the results of this experiment?

7. If the coefficient of friction between the two surfaces is .64, what horizontal force will be necessary to pull a 75-pound wooden crate across a concrete floor at a constant speed?

8. What force will be needed to pull the same crate from problem #7 up a 25° concrete incline?

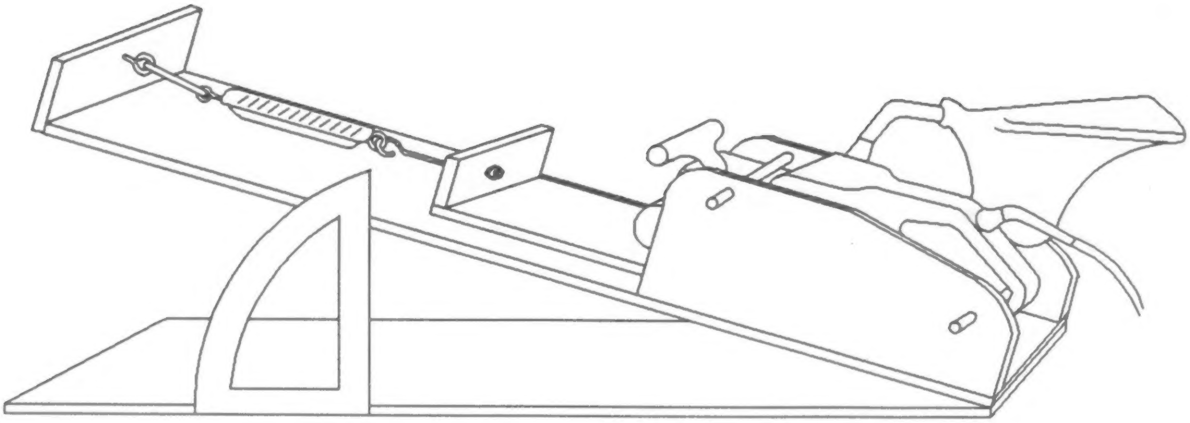


Figure M-7-1

Belt Sander Setup

Table M-7-1

Belt Sander Data--120 Grade

Trial	Angle of Plane (degrees)	Normal Force N (pounds)	Frictional Force f (pounds)
1	0		
2	10		
3	20		
4	30		
5	40		

Table M-7-2

Belt Sander Data--60 Grade

Trial	Angle of Plane (degrees)	Normal Force N (pounds)	Frictional Force f (pounds)
1	0		
2	10		
3	20		
4	30		
5	40		

ANTICIPATED PROBLEMS:

Multiple trials may be needed to do the experiment.

Have a new clean belt for the sander.

The surface between the ramp and the sanding plate should be as frictionless as possible, i.e., use ball bearings imbedded in the ramp.

Use a hardwood board for the sanding plate. Knots in the wood may cause uneven wear.

METHODS OF EVALUATION:

Answers to questions

Class discussion on friction

Quiz

FOLLOW-UP ACTIVITIES:

Test a variety of hard and soft woods with the the apparatus

Tour a plant to view industrial finishing systems' use of friction

Demonstrate a rock polisher

View the video "Total Surface Finishing."

Have the students investigate static friction associated with surface finishing by performing the following activity:

Friction of Finished Surfaces

Purpose: To measure the coefficient of friction between wood surfaces of varying smoothness.

Apparatus:

1 wood block, approximately 2" x 4" x 3"
1 unfinished board, approximately 1" x 6" x 18"
1 protractor
1 sanding block
1 coarse sandpaper
1 medium sandpaper
1 fine sandpaper
Varnish
1 brush

1. Cut a block of wood from a 2" x 4" wood block and sand it with a medium grade sandpaper.

2. Weigh the block and record the weight in Table M-7-3, "Follow-Up Data Table."

3. Cut an unfinished board approximately 1" x 6" x 18" and set the end of it against a rigid object so that it will not slide when the free end is lifted.

4. Place the block of wood on the free end of the unfinished board.

5. Slowly raise the free end of the board which has the block on it until the block begins to slide down the board.

6. Record the angle at which the block begins to slide.

7. Use the weight of the block and the angle to calculate the normal and the frictional forces acting on the block.

$$F_{normal} = F_{weight}\ (\cos\theta)$$

$$F_{frictional} = F_{weight}\ (\sin\theta\ )$$

8. Calculate the coefficient of friction (μ) for the block and board.

$$\mu = \frac{F(frictional)}{F(normal)}$$

9. Repeat the experiment four more times by using coarse, medium, and fine sandpaper to finish the board to various degrees of smoothness and end with the last trial after the board has been coated with varnish.

Table M-7-3

Follow-Up Data Table

Board Surface	Angle (degrees)	F_{normal} (pounds)	$F_{frictional}$ (pounds)	μ
Unfinished				
Coarse				
Medium				
Fine				
Varnished				

REFERENCES,
RESOURCES,
VENDORS:

K.V.F. Quad Corporation
1201 7th
East Moline, IL 61244
(309) 755-1101

For surface finishing video, write to:
Finishing & Associates, Inc.
975 Jaymor Rd., Suite #5
South Hampton, PA 18966
(215) 953-1340

BELT SANDER APPARATUS

Parts List:

1 - 3/4" x 6-3/4" x 34-1/2" plywood base

2 - 3/4" x 7" x 13" plywood sides

1 - 3/4" x 2-3/4" x 6-3/4" plywood rear block

1 - 3/4" x 2-1/2" x 6-3/4" plywood front block

2 - 3/8" x 1-1/4" x 18" plywood sanding plate guides

6 - ball bearings - 3/8" to 1/2" all the same size

2 - 1/2" dowel rods 10" long

2 - 1/4" x 1-1/2" eyebolt nut and washer

1 pound of 1-1/2" to 2" drywall screws

1 - 3/8" x 4-1/4" x 17-1/4" piece of solid wood (not plywood) for sanding plate

Assembly

Note: The belt sander test platform was built for the Porter Cable Model 360 Heavy Duty Dustless Belt Sander. If you do not have this model sander, you may have to modify your test platform to fit your sander.

1. Cut all pieces to the sizes listed in the Parts List. Check Figure M-7-2, "Belt Sander Apparatus Drawing," for detail information.
2. Start with the base. To reduce friction between the sanding plate and the base, drill six holes for the ball bearings. Drill about 2/3 the depth of the bearing and press wax or grease into the hole. Then press the bearings into the holes.

3. Fasten the sides to the base. The base fits between the sides. The rear block fits between the sides and on top of the base. Fasten all these parts with screws. Fasten the front block with the eye bolt to the front of the base as shown in Figure M-7-2.

4. The sanding plate guides are fastened to the base just inside the sides and touch the rear block. The space between them must be wider than the sanding plate which is 4-1/4" wide for the sander.

5. The sanding plate is a 4-1/4" x 17-1/4" x 3/8" solid wood (not plywood). One end has a 3/4" x 2" x 4" block screwed on to hold the other eye bolt. The sanding plate sets on the bearings between the sides. Place the sander on the plate and place the dowel rods in the holes to hold the sander in place. This setup is fastened on an adjustable inclined plane for testing.

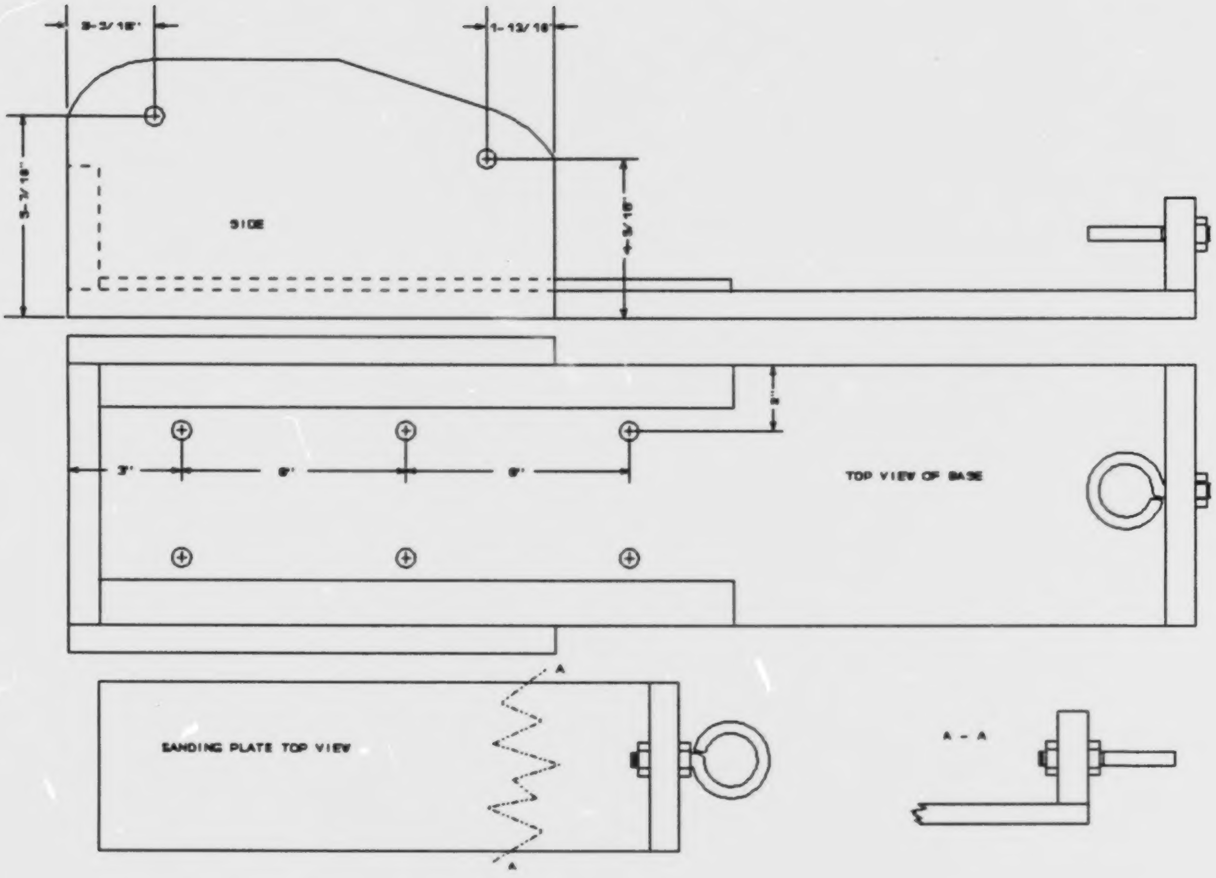

3-3/16"
1-13/16"
5-7/16"
4-3/16"
SIDE
2"
3"
8"
8"
TOP VIEW OF BASE
A
A
SANDING PLATE TOP VIEW
A - A

Figure M-7-2

Belt Sander Apparatus Drawing

FRICTION BELT SANDER MATHEMATICS WORKSHEET

Right Triangles and Trigonometric Functions

Note: A prerequisite for this worksheet is a discussion of vectors.

Facts about right triangles:
(See Figure M-7-3, "Triangle A.")

- Contain one 90° angle.
- The other two angles are called acute (have measures of less than 90°).
- Contain three sides; the longest side is directly across from the right angle and is called the hypotenuse.
- The shorter sides are called legs.
- The sum of the three angles is 180°.

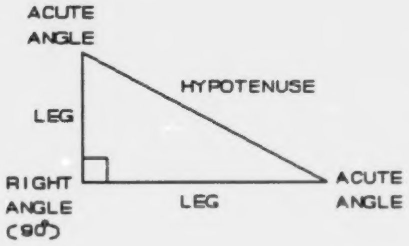


Figure M-7-3

Triangle A

Trigonometric functions can be used to determine angle measurements, unknown lengths or, in the case of vectors, unknown forces, velocities, and other vector quantities.

The trigonometric functions used here will be sine, cosine, and tangent. Their definitions are as follows (see Figure M-7-4, Triangle B"):

$$\sin\theta = \frac{a}{h} = \frac{\text{opposite lef}}{\text{hypotenuse}}$$

$$\cos\theta = \frac{b}{h} = \frac{\text{adjacent leg}}{\text{hypotenuse}}$$

$$\tan\theta = \frac{a}{b} = \frac{\text{opposite leg}}{\text{adjacent leg}}$$

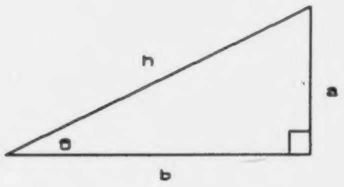


Figure M-7-4

Triangle B

The expression sinθ is read as "sine of theta," where theta is the acute angle. Sin, cos, and tan are abbreviations for sine, cosine, and tangent, respectively. These ratios are always written with respect to a certain angle.

1. Using the triangle in Figure M-7-5, "Triangle C," write the ratios for each of the following:

sinA = sinB =

cosA = cosB =

tanA = tanB =

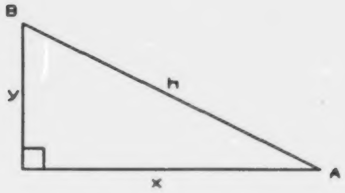


Figure M-7-5

Triangle C

The following example will illustrate how to determine the values associated with the legs of a right triangle, given information about the hypotenuse and one acute angle.

2. c is a vector quantity of force. Find the magnitude (size) of its perpendicular components (see Figure M-7-6, "Triangle D").

$c = 45$ N

$\theta = 23^\circ$

First, write the correct ratios using the labels given.

sinθ = cosθ = tanθ =

To find "a," use sinθ.

Rearrange the equation. Solve for "a."

$a = \sin\theta \times c$

$a = \sin(23^\circ) \times (45\ N)$

$a = 0.3907 \times 45\ N$

$a = 17.6\ N$

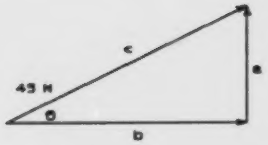


Figure M-7-6

Triangle D

To find "b," use cosθ.

Rearrange the equation. Solve for "b." Complete as for "a."

Thus, the magnitudes of the components of the 45 N force are 17.6 N and __________.

Try the following problem using the above method.

3. A balloon is ascending at a rate of 12 ml/hr at an angle of 55 with respect to the ground. Find the speed of the wind pushing the balloon sideways and the vertical speed of the balloon (see Figure M-7-7, "Triangle E").

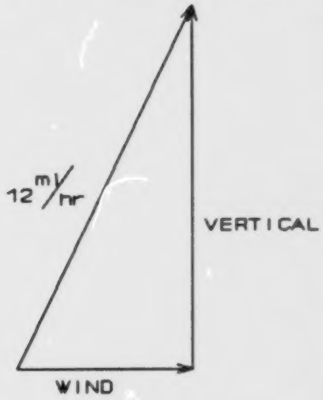


Figure M-7-7

Triangle E

ACTIVITY 8: VARIABLE RESISTANCE (DIMMER SWITCH)

TECHNOLOGICAL FRAMEWORK:

Wherever electricity is used, there is a need to control current for lighting and motor speed. In the following activity, three methods of controlling current will be examined. The first uses a rheostat to vary the resistance of the circuit. In the second, the coil/core setup is similar to DC speed control motors used on conveyors. Finally, the "dimmer" is used in lighting and to control speeds on fans and other variable speed tools.

PURPOSE:

To use various methods of changing current in a simple circuit. These include a rheostat, a coil with core, and a household dimmer switch.

To study the power in circuits using a rheostat and a coil with core.

To observe the relationship between voltage, resistance and current (Ohm's Law) using a rheostat.

To observe the effect of inductance in a simple circuit.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--DC and AC circuits, resistance, Ohm's Law, inductance, power, efficiency, impedance

Mathematics--direct proportions, inverse proportions, slope

Technology--circuit control, power transfer, environmental control

PRE-REQUISITES:

Electrical symbols
Wiring procedures
Reading meters
Knowledge of inductance
Direct proportions
Inverse proportions
Slope

MATERIALS, EQUIPMENT, APPARATUS:

Toggle dimmer switch
Variable AC/DC power supply
12 volt, 50 watt light bulb
120 volt, 40 watt light bulb
Rheostat (5 ohm, 4.47 amp)
3 wire cord with male plug
wire cord (made from 10 pc. of coat hanger wire wrapped with tape)
Digital multimeter
Oscilloscope
Lamp socket
Air core solenoid

TIME FRAME: 90 minutes

TEACHING STRATEGIES:

Physics or Technology lab
Physics or Technology teacher for presentation
Mathematics teacher to assist in analysis of data

TEACHING METHODOLOGY:

1. A discussion of Ohm's law and its relationship should accompany this activity. If presented during the post-lab, the activity may be perceived as exploratory or the Ohm's Law discussion could begin the activity.

2. Before doing the second part of the activity, it will be necessary to explain inductance to the students.

3. Dimmer switches and rheostats can be premarked for settings.

4. Explain safety procedures. Emphasize connecting leads to the proper scale and setting the dial to the correct range if using analog meters.

5. When doing the dimmer portion of the experiment, make sure the connection points across the light bulb for the oscilloscope are insulated to protect from shock. If this is not possible, it would be best to use this portion of the activity as a demonstration.

6. The dimmer portion of the activity refers to the dimmer as being "clicked off." The purpose of this is to show the students that without "clicking off" the switch, current is still being used in the circuit even though the lights appear to be "off." Not all dimmers behave this way, however, and you may want to adjust the activity by having the students do fewer wave sketches.

FURTHER FIELDS OF INVESTIGATION:

This activity involves resistance in electrical systems; other forms of resistance can be found in other systems. In the following examples, there are quantities which behave similar to electrical resistance and current.

Mechanical System: The pressure on a clutch creates more friction causing speed to slow down.

Fluid System: In a hydraulic system, when the valve is closed, the resistance is increased and fluid flow is decreased.

PROCEDURE:

Light dimmers have varied uses from saving money on home electric bills to creating atmosphere in restaurants. Similar types of switches can be found on ceiling fans to adjust the speed on the fan motors. This application of speed control is widely used in industry to control the speed of conveyors in production lines.

In this lab, you will analyze three methods of dimming light bulbs: using a rheostat, using a coil with a core, and using a household dimmer switch.

In the rheostat circuit, you will measure the voltage and current and construct a graph of your data to find the resistance of a light bulb. You will also examine the power consumption of the circuit.

Using the coil with the core, you will measure the voltage and current and calculate the power of the bulb, core, and source and determine the relationship between them. With this circuit, you will connect the oscilloscope to observe the waveform produced.

For the household dimmer switch, you will connect the oscilloscope and sketch the waveform produced at four different dimmer switch positions.

Setup #1 - Rheostat

1. Connect the apparatus according to Figure M-8-1, "Rheostat Diagram."

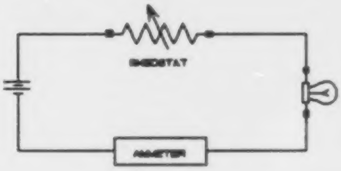


Figure M-8-1

Rheostat Diagram

2. If you are using a rheostat which has exposed windings, mentally trace the path that the current makes around the rheostat. Note that by changing the position of the dial, one is changing the amount of conducting material through which the current passes.

3. Have your instructor check your wiring of the circuit.

4. With the rheostat set for minimum resistance, turn on the DC power supply to 9 volts. (DO NOT turn the power supply above 12 volts.)

5. Turn the rheostat switch to the first position. Read the current and record it in Table M-8-1, "Rheostat Data Table."

6. Test the voltage across the power supply, the rheostat, and the light bulb. Record these values in Table M-8-1.

7. Repeat steps 5 and 6 for settings 1/2, 3/4, and full turn.

8. Using the relationship P = IV, calculate the power for each element.

The power input by the DC supply should equal the total power output of the rheostat and the light bulb. Check to see if this is true. What would cause any discrepancies?

9. Graph the voltage vs. current for the light bulb. Use a straight line to connect the points.

10. Find the slope of the line. What quantity does this slope represent?

Table M-8-1

Rheostat Data Table

Trial	Rheostat Position	Current (amps)	Rheostat Voltage (volts)	Light Voltage (volts)	Source Voltage (volts)	Rheostat Power (watts)	Light Bulb Power (watts)	Source Power (watts)
1	1/4							
2	1/2							
3	3/4							
	full							

PHYS-MA-TECH
AN INTEGRATED PARTNERSHIP

Setup #2 - Coil with Core

1. Connect circuit as shown in Figure M-8-2, "Coil with Core Diagram."

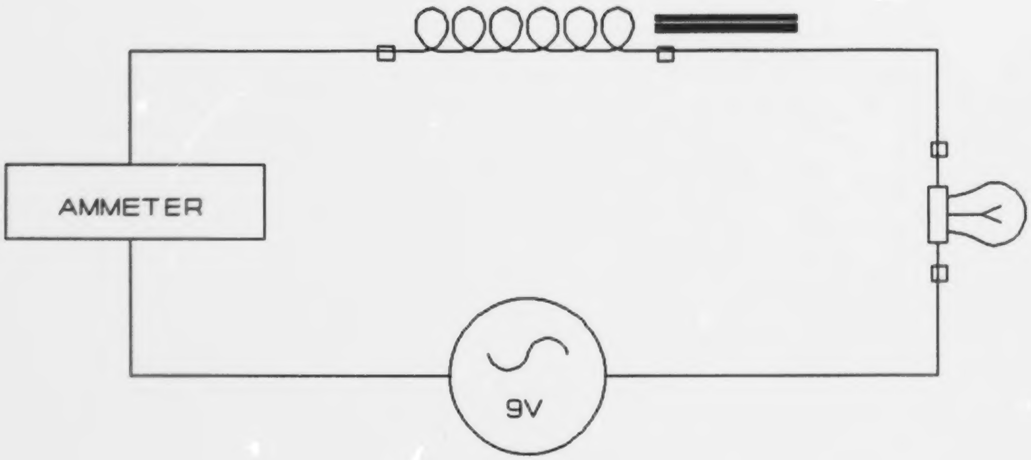


Figure M-8-2

Coil with Core Diagram

2. Without the core in the circuit, set the power supply voltage to 9 volts AC. (DO NOT turn the power supply above 12 volts.)

3. Set the multimeter on the 10 amp scale and record the current of the circuit in Table M-8-2, "Coil with Core Data."

4. Test the voltage across the power supply, the coil, and the light bulb. Record the results.

5. Repeat steps 3 and 4, placing the core 1/4, 1/2, 3/4, and fully in the coil. (Someone will need to hold the core as it will tend to be pulled into the coil by the magnetic field.)

6. Using the relationship P = IV, calculate the output power for each element and record in Table M-8-2.

7. Compare the source power to the power consumption for the circuit.

8. Connect an oscilloscope across the coil. Using the oscilloscope grids in Figure M-8-3, "Oscilloscope Grid--1/4 Position" and Figure M-8-4, "Oscilloscope Grid--3/4 Position," make sketches of the signal on the screen at the 1/4 and 3/4 positions of the core.

9. After looking at the sketches of the screen, describe what (if any) changes take place in the amplitude and period of the signal when the core is inserted into the coil.

1/4 of the core
inserted into the coil

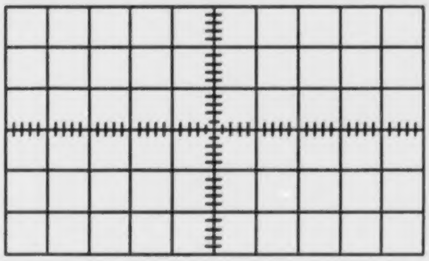


Figure M-8-3

Oscilloscope Grid--1/4 Position

3/4 of the core
inserted into the coil

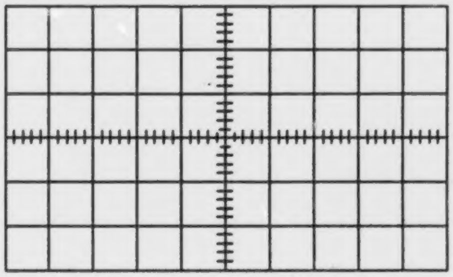


Figure M-8-4

Oscilloscope Grid--3/4 Position

Table M-8-2

Coil with Core Data

Trial	Core Position	Current (amps)	Coil Voltage (volts)	Light Voltage (volts)	Source Voltage (volts)	Coil Power (watts)	Light Power (watts)	Source Power (watts)
1	coil alone							
2	1/2							
	3/4							
	full							

CAUTION: THE FOLLOWING ACTIVITY MAKES USE OF A 120 VOLT AC SOURCE. USE CARE WHEN MAKING CONNECTIONS.

Setup #3 - Dimmer Switch

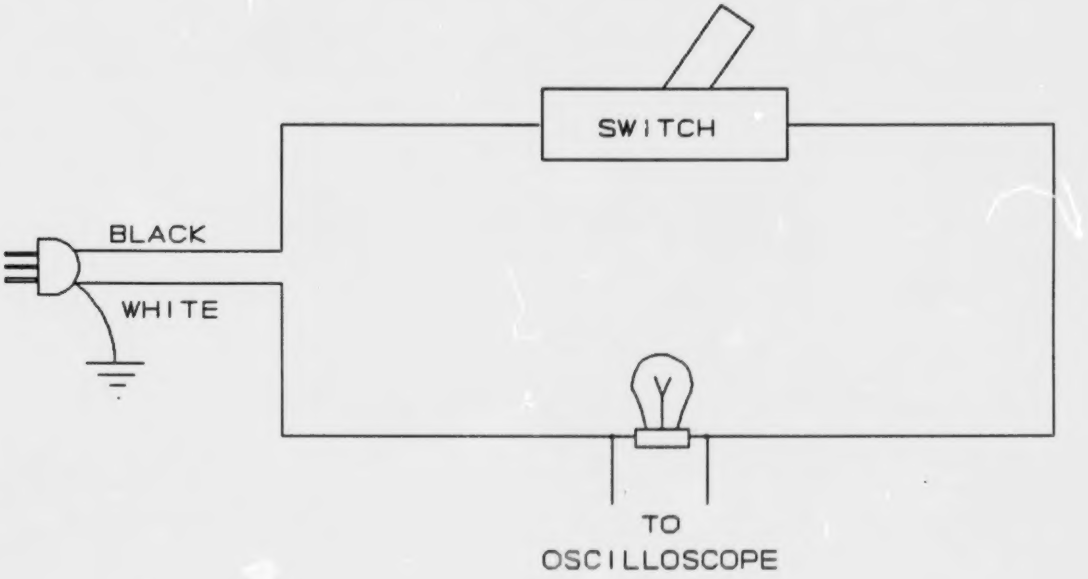


Figure M-8-5

Dimmer Switch Diagram

1. Connect the circuit according to Figure M-8-5, "Dimmer Switch Diagram." Make all connections before plugging in the circuit. Be sure that the oscilloscope is connected across the bulb only. Set the voltage control on the scope for 50 v/cm and the time at 2 ms/cm.

2. Plug in the light and turn on the dimmer switch until it "clicks" in the "on" position. Use Figure M-8-6, "Oscilloscope Grid--Clicked," and make an accurate sketch of what is seen on the screen. Be sure to show at least one complete cycle.

3. Record the peak voltage and the period of the signal (the time for one complete cycle).

   a. To find the period (T), count the divisions between consecutive peaks.

   b. Multiply the number of divisions by the time setting on the oscilloscope.

   _____div/cycle x _____sec/div = _____ sec/cycle

   peak voltage__________ Period__________

4. Repeat step 3. This time, have the switch fully "on" but not "clicked." Note that the shape of the signal has changed. Carefully sketch at least one complete cycle on Figure M-8-7, "Oscilloscope Grid--On," and record the peak voltage and period. Also record the amount of time during one cycle that the voltage appears to be non-zero.

5. Repeat step 4 with the switch at the mid position. Sketch what you see on Figure M-8-8, "Oscilloscope Grid--Mid Position."

   peak voltage__________ Period__________

6. Repeat again. This time have the switch at the position just before it "clicks" off. Sketch the signal on Figure M-8-9, "Oscilloscope Grid--Low."

   __________peak voltage Period__________

   non-zero time__________

7. From the waves you have drawn, summarize your observations of the effect of the dimmer switch on the circuit.

8. In each trial, calculate the percentage of each cycle that the voltage was "on" by dividing the non-zero time by the period and multiplying by 100.

"Clicked on"

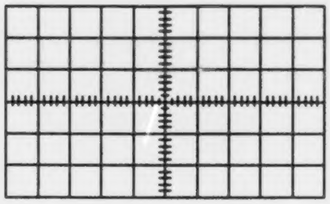


Figure M-8-6

Oscilloscope Grid--Clicked

"On"

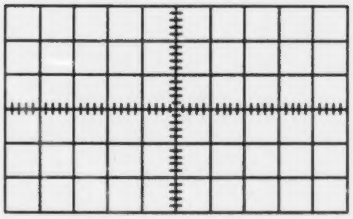


Figure M-8-7

Oscillator Grid--On

"Mid Position"

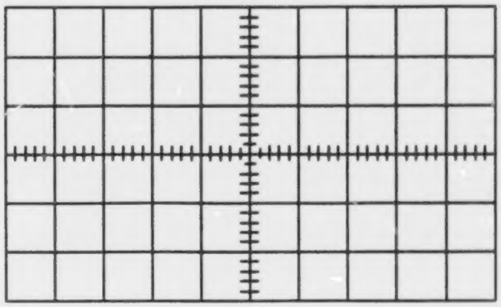


Figure M-8-8

Oscillator Grid--Mid Position

"Almost Off"

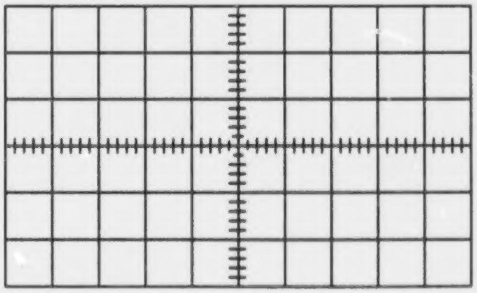


Figure M-8-9

Oscillator Grid--Low

ANTICIPATED PROBLEMS:

The light dimmer must be used with 120 volts AC. Connections must be made with care or damage to equipment may result.

Students may tend to burn out the 12 volt bulbs.

METHODS OF EVALUATION:

Student graphs
Answers to questions
Class discussion
Follow-up quiz
Observation during the activity

FOLLOW-UP ACTIVITIES:

(Including alternate activities)

Connect a model train to the motor and have students predict what will happen to the train as the rheostat or dimmer switch is regulated.

Hook up a tachometer to an electric motor to see how RPMs vary with the levels of resistance. A disk emblazoned with the school symbol could also be attached to the motor shaft and the speed changes could be observed with a stroboscope.

Use a light meter to see how light intensity varies with current.

Vary the load resistance to illustrate the maximum power transfer condition.

REFERENCES, RESOURCES, VENDORS:

W. W. Grainger, Inc.
333 Knightsbridge Pkwy.
Lincolnshire, IL 60069

POST-LAB QUESTIONS: DIMMER SWITCH

1. In Setup #1, what happens to the brightness of the bulb when the resistance of the rheostat is increased?

2. Do the measured voltages in the rheostat circuit follow the voltage rule for series circuits?

3. Does the coil with core system gain efficiency as it dims the light bulb?

4. In Setup #2, why does inserting the coil cause the light bulb to dim?

5. In terms of energy conservation, why might the dimmer switch be better than the coil/core method for controlling lighting?

VARIABLE RESISTANCE - DIMMER SWITCH MATHEMATICS WORKSHEET

Oscilloscope Worksheet

The oscilloscope has the settings given in Figure M-8-10, "Oscilloscope Triangular," for the triangular wave shown on the CRT (cathode ray tube).

Find the period, frequency, and the peak-to-peak voltage (amplitude) of the signal.

Step 1: The **PERIOD** of one cycle:

The "time/div" control is set at 15 msec (milliseconds) per division. The number of divisions for one period (count from A to B on the grid face) is approximately 4.5 divisions.

Therefore, period (T) is:

$$15 \frac{\text{msec}}{\text{div}} \times 4.5 \text{ div} = 67.5 \text{ msec}$$

Step 2: The **FREQUENCY** of one cycle:

$$f = \frac{1}{T} = \frac{1}{67.5 \text{ msec}} = \frac{1}{67.5 \times 10^{-3}\text{sec}} = \frac{1}{0.0675 \text{ sec}} = 14.8 \times \frac{1}{\text{sec}}$$

$$f = 14.8 \times \frac{1}{\text{sec}} = 14.8 \text{ Hz}$$

Step 3: The amplitude of the voltage signal, **PEAK-TO-PEAK**:

The "volt/div" control is set to 0.5 volts/div. Counting the number of divisions from the high point of the signal to the low point of the signal yields 6 divisions.

Therefore, peak-to-peak voltage is:

$$0.5 \frac{\text{volts}}{\text{div}} \times 6 \text{ div} = 3.0 \text{ volts peak-to-peak}$$

Use this method to complete the following problems:

1. Find the peak-to-peak voltage, period, and frequency of the square waveform, given the control settings shown in Figure M-8-11, "Oscilloscope Square Wave."

2. Find the peak-to-peak voltage, period, and frequency of the sine waveform, given the control settings shown in Figure M-8-12, "Oscilloscope Sine Wave."

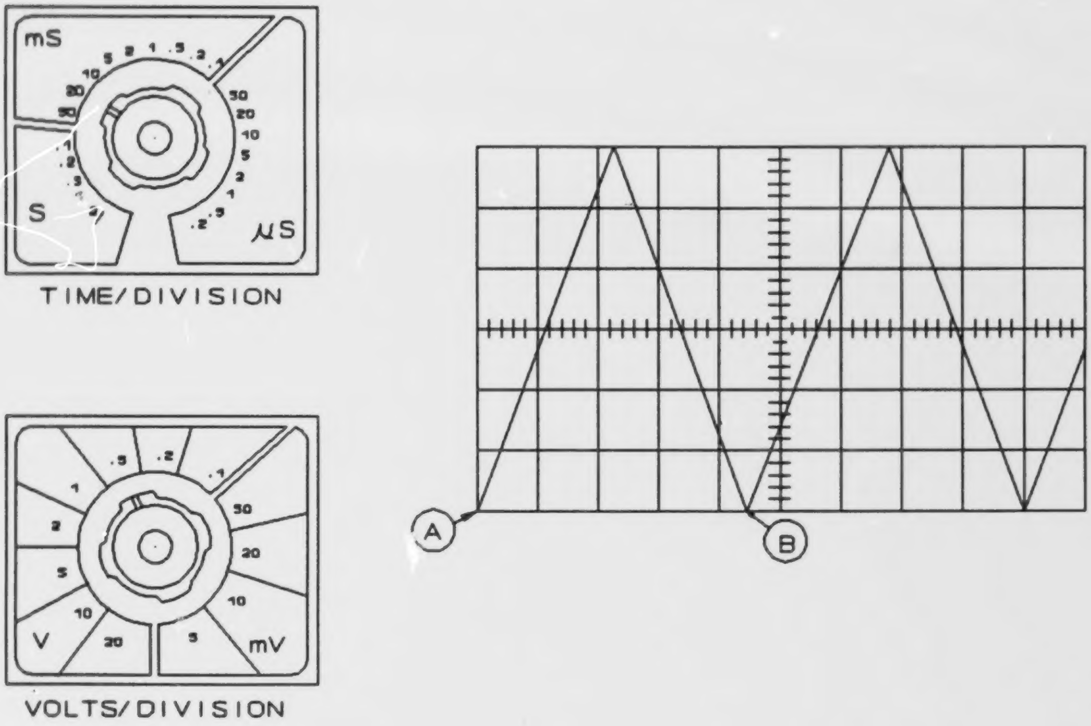

mS
5
2
1
.5
.2
.1
10
20
50
50
20
10
5
2
1
.5
.2
.1
.2
.5
1
2
S
µS
TIME/DIVISION
.5
.2
.1
1
2
5
10
20
50
20
10
5
V
mV
VOLTS/DIVISION
A
B

Figure M-8-10

Oscilloscope Triangular Wave

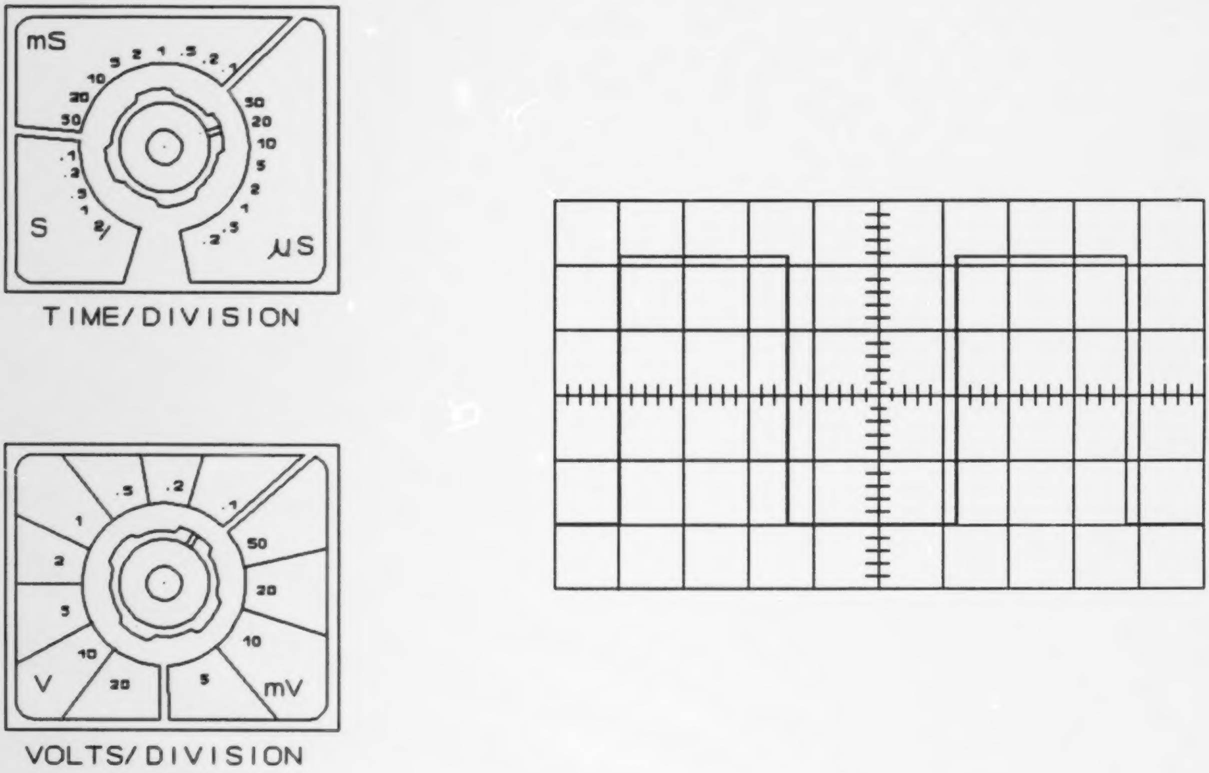

mS
10
5
2
1
.5
.2
.1
20
50
50
20
10
5
2
1
.5
.2
µS
.1
.2
.5
1
2
S
TIME/DIVISION
.5
.2
.1
1
2
5
10
20
V
50
20
10
5
mV
VOLTS/DIVISION

Figure M-8-11

Oscilloscope Square Wave

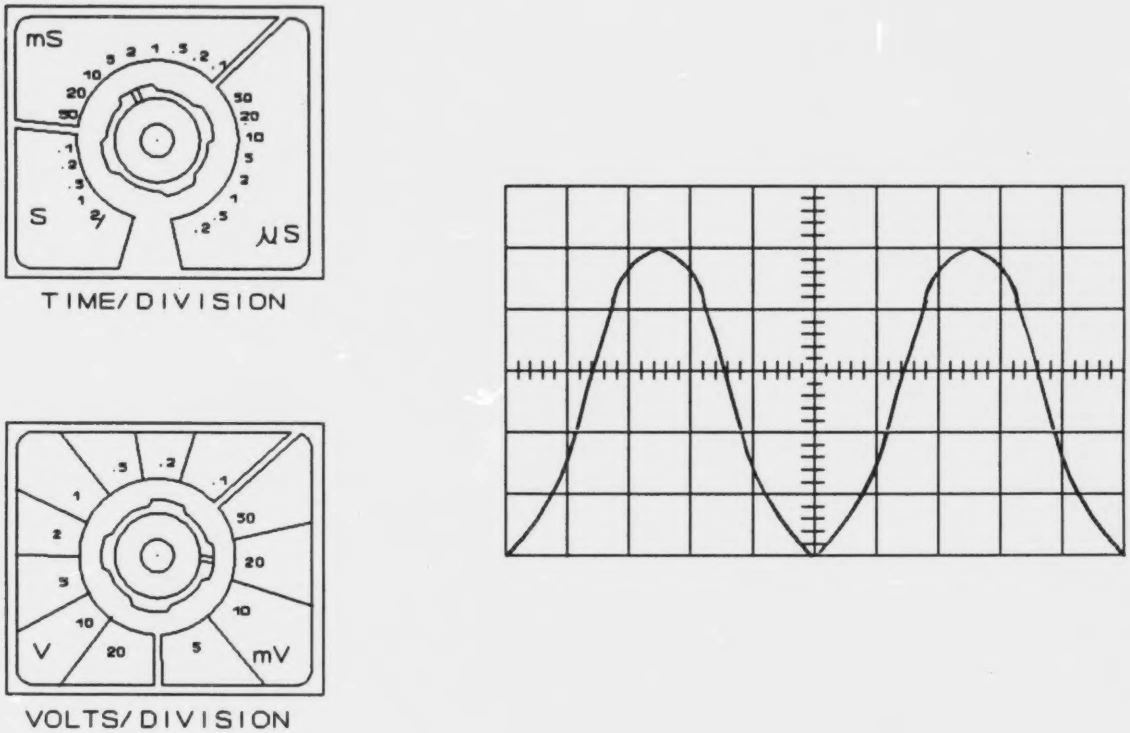

mS
50
20
10
5
2
1
.5
.2
.1
50
20
10
5
2
1
.5
.2
.1
.2
.5
1
2
S
µS
TIME/DIVISION
.5
.2
.1
50
20
10
5
mV
1
2
5
10
20
V
VOLTS/DIVISION

Figure M-8-12

Oscilloscope Sine Wave

DIMMER SWITCH MATHEMATICS WORKSHEET

Prefixes and Multipliers

When working with very large or very small numbers, scientific notation is used to ease the reading of those numbers, simplify calculations, and conserve space. Even scientific notation, however, can be too space-consuming when used to show values on the small dials and displays of electrical instruments. In these cases, instead of scientific notation, symbols for prefixes representing various powers of 10 are used. Following is a table showing some of the common prefixes, their symbol, and the multiplying factor they represent.

Prefix Name	Prefix Symbol	Multiplying Factor
giga	G	10^9
mega	M	10^6
kilo	k	10^3
hecto	h	10^2
deka	da	10^1
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Write a prefix to take the place of the multiplier in the following examples:

1. 10^{-3} volts = ________________
2. 10^{-12} farads = ________________
3. 10^{-6} amperes = ________________
4. 10^{3} watts = ________________
5. 10^{6} cycles = ________________

The above example illustrates the change from a power of 10 multiplier to a prefix.

The prefix name given to 3.4 x 10^6 watts is 3.4 megawatts.

Complete the following using the number given and substituting the proper prefix for the multiplier.

6. 4.5×10^3 cycles = ________________
7. 2.7×10^{-6} farads = ________________
8. 7.1×10^6 ohms = ________________
9. 0.5×10^9 watts = ________________
10. 5.9×10^{-3} volts = ________________

When reading multimeters and oscilloscopes, the number displayed on the instrument must be multiplied by the appropriate prefix value to be correctly interpreted.

For example, when measuring resistance, the display may read 0.25. If the device is set to measure kΩ, the actual value is 0.25Ω which equals 0.25×10^3 ohms or 250 ohms.

Using the above example, rewrite the following readings, translating the prefixes to numerical quantities. Include the basic unit with your answer.

11. 0.54 mA = ________________
12. 3.67 k = ________________
13. 4.3 ms = ________________
14. 5.92 pf = ________________
15. 7.1 Mv = ________________

Just for fun, substitute the proper prefix for the following multiplying factors. The first one is done for you.

16. 1×10^6 phones = 1 megaphone
17. 1×10^1 cards = ________________
18. 1×10^{-12} boos = ________________
19. 2×10^3 mockingbirds = ________________
20. 1×10^{-6} phones = ________________

ACTIVITY 9: EXERCISE MACHINES

TECHNOLOGICAL FRAMEWORK:

Much like the "Little Old Ant" who wanted to move the rubber tree plant, people need to apply forces to move large objects. Unlike the ant, however, mankind uses machines to help with the task.

In this activity, the student will be observing characteristics of various simple machines involved with exercise equipment.

PURPOSE:

To survey a variety of exercise equipment by:

Finding the work input and output and calculating the efficiency of the machines.

Investigating the relationship between angle and force.

Examining torque.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--force, work and simple machines, vectors (force components), power, mechanical advantage, efficiency

Mathematics--formula manipulation, trigonometry functions

Technology--work and force in the utilization of mechanical devices

PRE-REQUISITES: Simple machines
Vectors
Proportions

MATERIALS, EQUIPMENT, APPARATUS:

Leg-lift machine	Meter stick
Low pulley	Spring scale (100 lb.)
Shoulder press	Protractor
Leg press	Digital bath scale

TIME FRAME: 60 minutes

TEACHING STRATEGIES: Weight room
Physics and Technology teachers
Mathematics teacher will assist those with weak prerequisites

TEACHING METHODOLOGY:

1. Have a class discussion on work and simple machines. Be sure to include the vector nature of force and vector components.

2. Break students into groups. (The size of the group will vary according to the amount of available equipment.)

3. Review the activity.

4. When performing the activity, the students may rotate through all machines or the teacher can assign each group to a single machine and then each student will share his or her findings with the rest of the class.

5. When performing the high or low pulley experiments, use a spring scale (a fish weighing scale will do) to demonstrate to the students that the force needed to pull on the wire is independent of the angle at which the force is applied.

6. When doing the chest pull, best results will be obtained with students of average height and who weigh 150-180 pounds. Students who are tall or very thin will have difficulty staying on the scale when pulling on the wire. Also, the students performing the experiment must pull with their arms; they must not lean back when pulling.

7. The "high pulley" activity can also be done with a low pulley except that the apparent weight would be increased instead of decreased.

FURTHER FIELDS OF INVESTIGATION:

Machines are devices which have been designed to to work for man. Work is done when a force causes something to move or change. Bottle openers, pry bars, wheel barrows, see-saws, cranes, jacks, screws, wrenches, pulleys, and motors are only a few of the seemingly endless number of machines we use. Even our own structure of bone and muscle is a simple machine.

PROCEDURE:

In this lab, you will measure forces necessary to operate certain exercise machines in order to study work and torque.

Using the leg press, you will compute the torque produced by measuring the lever arm and applied force.

When analyzing the chest press, you will measure forces and the distance through which they are applied to investigate work and its conservation in simple machines.

Leg Lift

1. Set the load on the leg lift apparatus (Figure M-9-1, "Leg Lift Diagram") at 10 pounds.
2. Mark distances of 10", 12", 14", and 16" from the pivot point. (It may be necessary to attach a wire around the bar at each distance in order to hook on the scale. Be careful of slippage when applying the force.)
3. Convert the previous measurements to feet and record them in Table M-9-1, "Leg Lift Data."
4. Place a wire lifting ring at the 16" mark, hook the spring scale to the wire, and lift the bar a small distance. Record the force needed to lift the bar.
5. Repeat step 4 using the other positions.
6. Using the formula Torque = Force x Distance, calculate the torque for each trial.
7. Average the torque values.

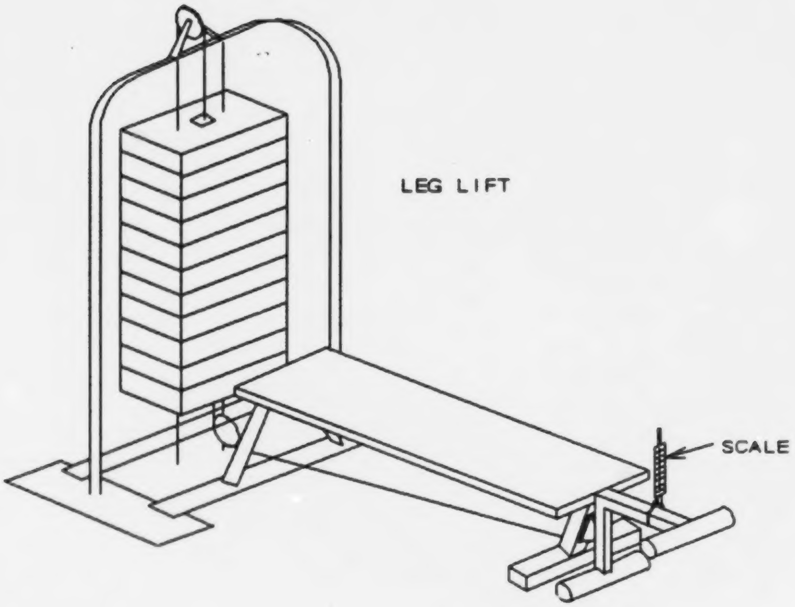


Figure M-9-1

Leg Lift Diagram

Table M-9-1

Leg Lift Data

Distance (inches)	Distance (feet)	Force (pound)	Torque (ft lb)
9			
12			
15			
18			

Shoulder Press/Chest Press

1. Locate the pivot of the apparatus and determine where the load and effort forces are to be applied.

   What class lever is this?__________

2. Set the machine at 10 pounds.

3. Attach a wire across the "handle bars" of the lever arm as shown in Figure M-9-2, "Shoulder/Press Diagram."

4. Using a spring scale attached to the wire, lift the lever 1/2 foot.

5. Record the force on the spring scale and the vertical distance moved by the load in Table M-9-2, "Shoulder/Chest Press Diagram."

6. Using the formula WORK INPUT = EFFORT FORCE X EFFORT DISTANCE, calculate the work input for the lever.

7. Simple levers are examples of machines which are nearly 100% efficient (there is always some loss due to friction in real systems). In other words, you get out most of what you put in. From the calculation of the work input and the measurement of the distance moved by the load, calculate the forces that would be needed to lift the arm at the "load position."

   WORK INPUT = WORK OUTPUT

   WORK INPUT = CALCULATED FORCE (at load pos.) x DISTANCE (moved by load)

   $$\frac{\text{WORK INPUT}}{\text{DISTANCE (moved by load)}} = \text{CALCULATED FORCE (at load position)}$$

8. Test the accuracy of your calculated prediction of force by attaching the spring scale at the load position and lifting. Record this as the "Measured Load Force."

9. Repeat the experiment using no load on the apparatus.

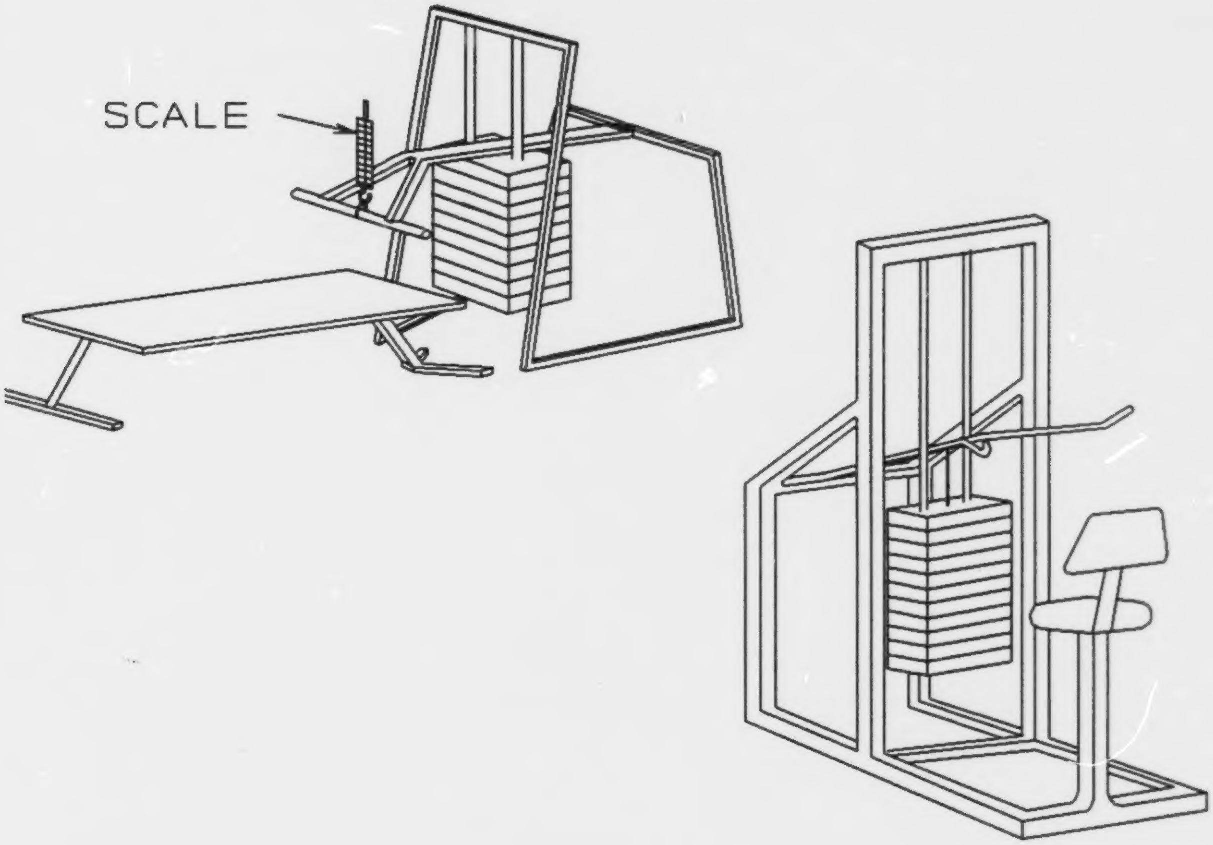


Figure M-9-2

Shoulder/Chest Press Diagram

Table M-9-2

Shoulder/Chest Press Data

Machine Setting (lb)	Effort Force (lb)	Effort Dist. (ft)	Work Input (ft. lb)	Load Dist. (ft)	Calculated Load Force (b)	Measured Load Force (lb)
10						
no load						

High Pulley

1. Record your "Actual" weight standing on the scale in Table M-9-3, "High Pulley Data."

2. Set the load on 10#.

3. Attach a spring scale to the bar and pull to lift the load. Check this force at different angles. You should observe that its value remains constant. Record this measurement under "Total Force" in Table M-9-3.

4. Place the bath scale at the base of the apparatus, stand on it, and pull straight down on the bar (0° with the vertical). Record this measurement under "Apparent Weight" in Table M-9-3.

5. Move the scale away from the apparatus and repeat step 4 using angles of 30, 45, and 60 degrees with the vertical. See Figure M-9-3 ("High Pulley"). Try to avoid leaning when pulling on the cable.

6. For each trial, find the difference between the "Actual" and "Apparent" weight values. This difference is the measured value of the vertical force acting on your body. Record the difference under "Weight Difference" in Table M-9-3.

7. Multiply the cosine of each angle by the Total Force." This will be the vertical component of the tension in the cable. Record this value under "Vertical Component."

8. Compare the measured (Weight Difference) and calculated (Vertical Component) values of force.

Table M-9-3

High Pulley Data

Data:

Actual Weight = __________ lb.

Total Force = __________ lb.

Angle (o)	Apparent Weight (pounds)	Weight Difference (pounds)	Cosine θ	Vertical Component (pounds)
0				
30				
45				
60				

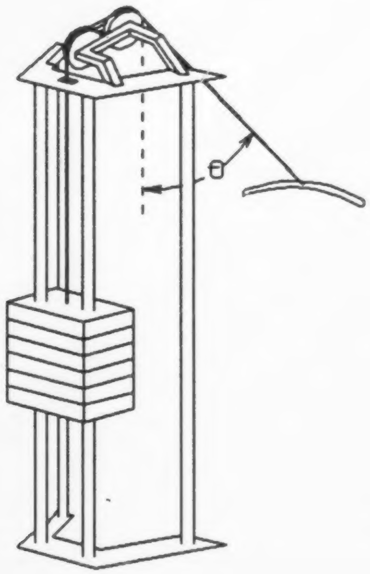


Figure M-9-3

High Pulley Diagram

ANTICIPATED PROBLEMS:

Have students apply the lifting forces through small distances on the shoulder press and leg lift.

Make sure when using the chest pull that the students don't lean backwards when pulling.

METHODS OF EVALUATION:

Class discussion

Answers to questions

Follow-up quiz

FOLLOW-UP ACTIVITIES:

Have a student design contest for the "effortless" weight machine. Study the use of block and tackle to increase the mechanical advantage of the machines.

Have a discussion of the physics of scales, including platform and spring scales.

Have students do an investigation which utilizes Hooke's Law.

REFERENCES, RESOURCES, VENDORS:

Weight training instructor:
Todd Rosenthal
Moline High School
3600 23rd Ave.
Moline, IL 61265

Universal Gym Equipment Co.
930 27th Ave.
Cedar Rapids, IA 52404
(319) 365-7561

POST-LAB QUESTIONS: EXERCISE MACHINES

1. In the "Leg Lift" activity, how do the torques for each trial compare?

2. Use the formula for torque and the average torque value from the "Leg Lift" to predict how much force would be needed to lift the load at a distance of 4 feet. How much would be needed at .5 feet?

3. For the "Shoulder Press, Chest Press," compare the input work for the two trials.

4. Compare the measured and calculated forces needed to lift the "Shoulder Press/Chest Press" load.

5. How does the angle of pull change the effectiveness of the high pulley?

6. For the high pulley, discuss the possible reasons for discrepancies between the measured and calculated values.

EXERCISE MACHINE MATHEMATICS WORKSHEET

The following formulas are useful when solving problems involving torque:

$T = F \times d$ where
T = torque
F = force
d = length of lever arm or distance from the pivot point

$F \times d = F' \times d'$ where
F = applied force
d = length of lever arm
F' = output force
d' = length of lever arm

1. To determine the motor size necessary for a particular conveyor, it is necessary to compute the break away torque of the conveyor. A technician attaches a wrench of length 18 inches to the shaft of the conveyor. The other end of the wrench is connected to a spring scale. The force reading just as the conveyor starts to move is 28 lb. Find the break away torque.

2. A child weighing 45 lbs. is sitting 2.3 ft. from the pivot point of a teeter totter. Another child weighing 53 lbs. is on the other side of the teeter totter. How far from the pivot point must the second child sit so that the two will balance?

3. A large rock needs to be removed from a roadway. If the rock weighs 150 lb., the pry bar is 3 feet long, and the pivot point is positioned 1 foot from the rock, how much force is needed to move the rock?

ACTIVITY 10: GENERATOR

TECHNOLOGICAL FRAMEWORK:

Our lives depend on energy. The sun provides us with a seemingly endless supply of heat and light, but we need other forms of energy also. Fortunately, nature and mankind are able to take resources and convert them to useable energy forms. For example, the kinetic energy of a moving river can be changed into electrical energy by turning the turbine of a generator.

PURPOSE:

To study variations in voltage and current readings for different size loads

To calculate power for each load

To get a "feel" for the power needed to generate electricity

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--voltage, current, AC generators, power, Lenz's Law, Faraday's Law

Mathematics--dimensional analysis, formula manipulation

Technology--voltmeters, ammeters, generators

PRE-REQUISITES: Use of voltmeter

Use of ammeter

CO-REQUISITES: Dimensional analysis for changing units

MATERIALS, EQUIPMENT, APPARATUS:

1 - bicycle generator (see directions for construction at the end of this activity)
1 - control box (diagrams/instructions are at the end of this activity)
1 - 12 V battery (or power source)
4 - 12 V light bulbs each fitted with car cigarette lighter plug
1 - ammeter
1 - voltmeter

TIME FRAME: 45 minutes

TEACHING STRATEGIES: Physics or Technology lab

Physics or Technology teacher for presentation of Lenz's Law and generator setup

Mathematics teacher to assist in the power calculations

TEACHING METHODOLOGY: Discuss generators including Lenz's Law.

Have a discussion of the other forms of energy conversion such as chemical->electrical, light->electrical, or nuclear->electric. Also include other energy resources such as geothermal, wind, solar, and fossil fuels.

FURTHER FIELDS OF INVESTIGATION: Generators and alternators use magnetic induction to cause current to flow. The most common uses for generators/alternators would be in automobiles and in power stations.

PROCEDURE:

In this lab, you will study the effect of a load on a power source, in particular, an alternator. You will supply power to the alternator by first exciting the field with a car battery, then by pedaling a bicycle connected by belt to the alternator. Current and voltage will be measured for increasing numbers of light bulbs connected to the source, allowing you to compute power for different loads.

1. Connect the belt to the bicycle and to the generator.

2. Each team of students will take measurements. One student will try to maintain a constant rate while pedalling the bicycle. Another student will turn the "exciter" switch on, then off, and record the current and voltage.

3. Now, while the student continues to pedal, switch on the circuit connected to the first lamp. Record the current of the circuit and voltage across the bulb in Table M-10-1, "Generator Data Table."

4. Switch on the second lamp and repeat using the other loads listed below. If the student stops pedalling at any time, it will be necessary to "re-excite" the generator.

5. Using the formula P = I V, calculate output power for each load. Show conversion of units from volt-amps to watts. Record values in Table M-10-1.

Table M-10-1

Generator Data Table

	Voltage (volts)	Current (amps)	Power (watts)
No Load			
Load #1 (1 lamp)			
Load #2 (2 lamps)			
Load #3 (3 lamps)			
Load #4 (4 lamps)			

POST-LAB QUESTIONS: GENERATOR

1. What kind of simple machine connects the bicycle to the generator?

2. Why does the generator need an "exciter?"

3. What provides the input power in this system?

4. By examining the chart, compare the voltage for the different sized loads.

5. Also from the chart, compare the current required by load #1 to that of load #3. Which is larger? Why? Does this make sense, considering the effort used to pump the pedals?

6. Do you see a corresponding change in the power of each? Why?

ANTICIPATED PROBLEMS:

None.

METHODS OF EVALUATION:

Check students' graphs. (The voltage should be about the same for each load, while current should increase as load increases.)

Answers to student questions.

Hold class follow-up discussion.

FOLLOW-UP ACTIVITIES:

Use bicycle generator setup with 12 different appliances such as a fan, a hair dryer, and a TV.

Use bicycle generator setup with lamp and light meter. Get different meter readings by changing pedalling speed.

Connect a pressure-sensitive device to the pedal. Measure the input force being applied; calculate the input power and compare to the output.

Have the students do a study of the power consumed in their homes.

Tie the activity into optics by comparing incandescence with florescence.

REFERENCES, RESOURCES, VENDORS:

Iowa Illinois Gas and Electric Co.
Education Dept.
205 Perry St.
Davenport, IA 52802

W. W. Grainger, Inc.
333 Knightsbridge Pkwy.
Lincolnshire, IL 60069

Auto shop in school for alternator, belt

Machine shop to cut groove in tire

Local hardware store

GENERATOR APPARATUS

Generator Parts List

Exercise bicycle with solid tire (Excel); a regular tire will work
Car alternator (Delco Remy Model #1979867 321-43 85 amp)
Alternator bracket
V belt (Gates 8695 Extra Service 468N)
12 volt battery or a power source
Steel plate 1/4" x 8" x 16" (base)
2-1/4" x 4" bolts (legs)
1-3/4" x 3/4" x 8" steel tube
1-1/2" x 1" x 4" steel block (vertical bracket for alternator arm)
1-1/2" x 2" x 2" steel block (alternator base bracket)

Generator Assembly

Start with an exercise bicycle with a solid rubber tire such as Excel. A "V" groove needs to be cut in the tire to accept a "V" belt such as Gates 8695 Extra Service 468N.

If a solid-tired exercise bicycle can't be found, you can use an exercise bicycle with a regular tire. The tire will have to be removed and fiber tape (duct tape) placed on the inside of the rim to cover the spokes. This will prevent any damage to the belt by any rough ends on the spokes.

The plate that holds the generator/alternator is a 1/4" x 8" x 16" steel plate. The steel tube and steel blocks need to be welded to the plate. See Figure M-10-1, "Generator Platform Assembly" for details on assembly of the plate. This information is for a Delco Remy Model #1979867 321-43 85 ampere alternator. Other alternators may need a little modification as to the placement of the brackets.

Mount the steel plate to the front of the frame with 1/4" x 2" bolts and nuts. See Figure M-10-2, "Generator Assembly." The holes are drilled through the steel tube under the plate and line up with the front support for the bicycle. The alternator can be installed and the "V" belt put on. The belt must be tight enough so that it doesn't slip.

Control Box Parts List

4 - toggle switches
4 - 12 volt cigarette lighter outlets for bulbs or appliances
1 - buss bar
electrical wire

Control Box Assembly

The construction of the control box can be as elaborate or as simple as you want. Use the wiring diagram shown in Figure M-10-3, "Generator Control Box," to make the electrical connections.

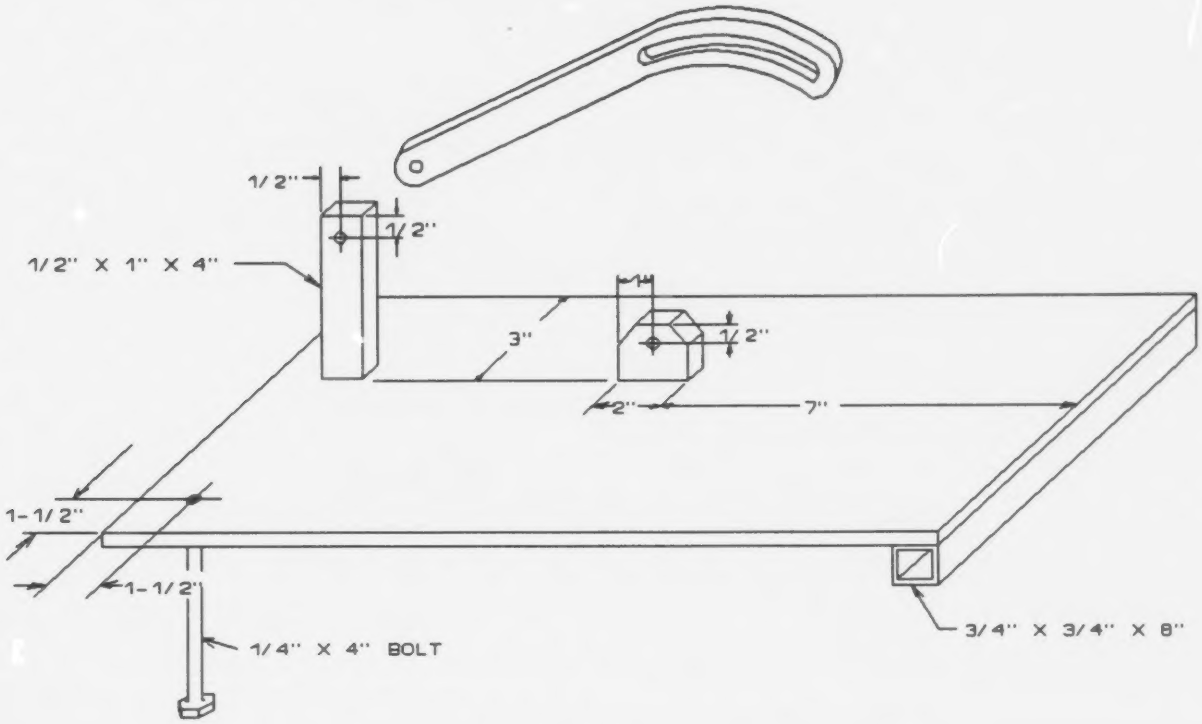

1/2"
1/2"
1/2" X 1" X 4"
3"
1/2"
2"
7"
1-1/2"
1-1/2"
1/4" X 4" BOLT
3/4" X 3/4" X 8"

Figure M-10-1

Generator Platform Assembly

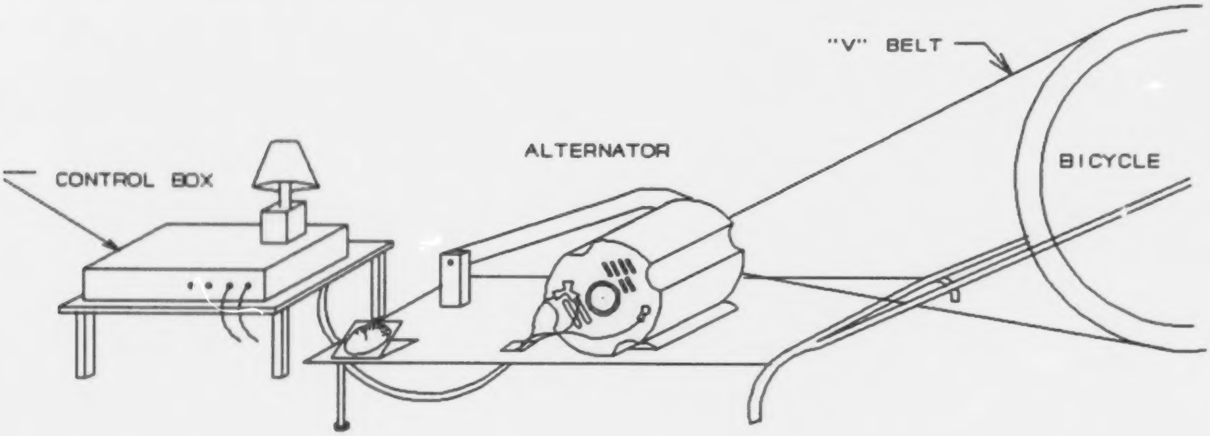

"V" BELT
ALTERNATOR
CONTROL BOX
BICYCLE

Figure M-10-2

Generator Assembly

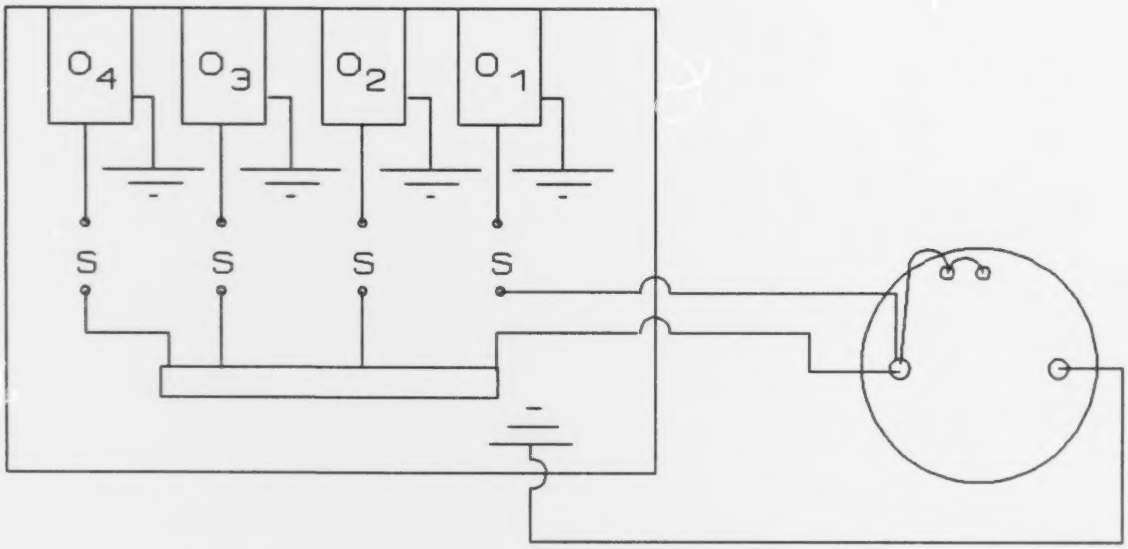


Figure M-10-3

Generator Control Box

GENERATOR MATHEMATICS WORKSHEET

Dimensional Analysis

Whenever one tries to perform functions with numbers, especially addition or subtraction, it is necessary that the labels on the numbers (units) be compatible or the quantities won't mix. For example, if you try to add 2 days to 8 hours, you don't arrive at an answer of 10 days or 10 hours. Before performing the addition, convert one of the quantities so that it has the same label as the other.

2 days is the same as 48 hours - so,

48 hours + 8 hours = 56 hours

Or, one could also think that:

8 hours is the same as 1/3 of a day - so,

2 days + 1/3 day = 2 1/3 days

Conversions are not always as simple as changing 2 days into 48 hours, so it is useful to learn a foolproof system to complete this task. This system is called "dimensional analysis."

To perform dimensional analysis, one must keep two ideas in mind:

1. Any quantity divided by its equivalent equals "one."
2. The value of any quantity multiplied by "one" remains unchanged.

To do the previous problem by this method, one must know the fact that one day is equivalent to 24 hours. According to the first rule, it can be said that:

$$\frac{\text{1 day}}{\text{24 hours}} = 1 \qquad \text{or} \qquad \frac{\text{24 hours}}{\text{1 day}} = 1$$

The above ratios are sometimes known as "converting factors."

To convert days into hours, the next step requires that one choose the appropriate converting factor and multiply the original quantity by that factor.

$$\text{2 days} \times \frac{\text{24 hours}}{\text{1 day}} = \text{48 hours}$$

Notice that the ratio was chosen which would allow "days" to cancel from the problem.

Following is a list of equivalents which may prove to be helpful in the following questions:

1 foot = 12 inches
1 yard = 36 inches
1 yard = 3 feet
1 mile = 5,280 feet
1 mile = 1,760 yards
1 watt = 1 joule/second
1 joule = 0.7376 ft lb
1 calorie = 3.086 ft lb
1 calorie = 4.184 joules
1 Btu = 1054 joules
1 kilowatt-hour (kWh) = 3.6 x 10^6 joules

1 meter = 100 centimeters
1 kilometer = 1000 meters
1 centimeter = 10 millimeters
1 horsepower = 746 watts
1 newton meter = 1 joule
1 volt coulomb = 1 joule
1 revolution = 2 π radians
1 minute = 60 seconds
1 hour = 60 minutes
1 inch = 2.54 centimeters

1. Write three ratios equivalent to 1 using the above list.

   __________ __________ __________

2. Convert feet to inches below by using the correct ration of 1.

   2.5 feet x __________ = __________ inches

   Does your answer seem reasonable?

3. Correct this problem:

   $$106 \text{ watts} \times \frac{746 \text{ watts}}{1 \text{ horsepower}} = 79{,}076 \text{ horsepower}$$

4. Complete the following:

   12 joules x __________ = __________ ft lb

   11.7 ft lb x __________ = __________ calories

Depending on the problem, it may be necessary to use more than one ratio. For example, to convert 12,000 inches to miles, there is no fact from the table that relates inches and miles. A chain of factors is needed to bridge this gap. To make this chain, each numerator is the same as the following denominator and the chain is finished when the desired units are in the numerator.

$$12{,}000\text{ inches} \times \frac{1\text{ foot}}{12\text{ inches}} \times \frac{1\text{ mile}}{5{,}280\text{ feet}} = 0.2\text{ miles}$$

The same result can be obtained through the use of different factors of 1. Again, start with the given unit (inches) in the denominator, but use a different conversion fact from the table.

$$5.\quad 12{,}000\text{ inches} \times \frac{\underline{\qquad\qquad}}{36\text{ inches}} \times \underline{1\text{ mile}} = 0.2\text{ miles}$$

Conversion between systems such as English to metric can also be performed with the dimensional analysis method. As an example, convert 6 feet to meters.

We know from the list that 1 inch = 2.54 centimeters; so to begin, convert feet to inches, then inches to centimeters, and finally centimeters to meters.

$$6\,\textit{feet} \times \frac{12\textit{ inches}}{1\textit{ foot}} \times \frac{2.54\textit{ cm}}{1\textit{ inch}} \times \frac{1\textit{ meter}}{100\textit{ cm}} = 1.8\textit{ meters}$$

6. What conversion factor would you begin with to convert the following?

6 kWh to Btu?

a. $\frac{778\text{ ft lb}}{1\text{ Btu}}$ b. $\frac{1\text{ Btu}}{1{,}054\text{ joules}}$ c. $\frac{3.6 \times 106\text{ joules}}{1\text{ kWh}}$

7. 15.3 yards to meters?

a. $\frac{36\text{ inches}}{1\text{ yard}}$ b. $\frac{2.54\text{ cm}}{1\text{ inch}}$ c. $\frac{1\text{ mile}}{1{,}760\text{ yards}}$

8. 17 joules to calories?

$$\text{a. } \frac{4.184 \text{ joules}}{1 \text{ calorie}} \qquad \text{b. } \frac{1 \text{ calorie}}{4.184 \text{ joules}} \qquad \text{c. } \frac{0.7376 \text{ ft lb}}{1 \text{ joule}}$$

9. Complete the conversions in #6-8.

Another application of dimensional analysis is required in problems dealing with rates which are usually written as ratios such as miles/hour. In this type of conversion, it is sometimes necessary to convert the numerator and the denominator to different units.

For example, convert $\frac{8 \text{ feet}}{\text{sec}}$ to $\frac{\text{miles}}{\text{hr}}$:

First change feet to miles:

$$\frac{8 \text{ feet}}{\text{sec}} \times \frac{1 \text{ mile}}{5{,}280 \text{ ft}}$$

Next, change seconds to minutes to hours, keeping the desired unit of time in the denominator.

$$\frac{8 \text{ feet}}{\text{sec}} \times \frac{1 \text{ mile}}{5{,}280 \text{ ft}} \times \frac{60 \text{ sec}}{1 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ hour}} = 5.45 \ \frac{\text{miles}}{\text{hr}}$$

Convert the following:

10. $300 \ \frac{\text{rev}}{\text{min}} \times \underline{\hspace{3cm}} \times \underline{\hspace{3cm}} = \underline{\hspace{3cm}} \ \frac{\text{rad}}{\text{sec}}$

11. $1{,}560 \ \frac{\text{rad}}{\text{sec}} \times \underline{\hspace{3cm}} \times \underline{\hspace{3cm}} = \underline{\hspace{3cm}} \ \frac{\text{rev}}{\text{min}}$

12. $60 \ \frac{\text{mi}}{\text{hr}} \times \underline{\hspace{3cm}} \times \underline{\hspace{3cm}} = \underline{\hspace{3cm}} \ \frac{\text{ft}}{\text{sec}}$

ACTIVITY 11: LASER SURVEY

TECHNOLOGICAL FRAMEWORK: There is an increasing number of commercial uses for laser beams (a.k.a. lasers) including those in the surveying industry. Surveyors use laser beams to align pipelines, hang ceilings, level sport grounds, check elevations, and for other conventional measurements. Lasers can provide greater accuracy, perform for longer distances, and save time for the surveyor.

PURPOSE: To use a laser to measure the speed of light.

To use a laser beam as a tool for measurement.

To use an oscilloscope to measure time by examining phase shifts of two signals.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--reflection, refraction, phase

Mathematics--rate, formula manipulation

Technology--surveying, lasers

PRE-REQUISITES: Use of an oscilloscope

Light/wave characteristics

MATERIALS, EQUIPMENT, APPARATUS:	Dual channel oscilloscope Modulated laser Speed of light/laser video kit (Sargent-Welch)
TIME FRAME:	30 minutes (more time needed to set up the apparatus)
TEACHING STRATEGIES:	Physics or Technology lab, hallway Performed by Physics or Technology teacher Mathematics or Technology teacher can guide students through a survey activity using a transit.
TEACHING METHODOLOGY:	Prepare students by discussing the wave properties of light. Be sure to include refraction through lenses and total internal reflection (beam splitter). Include a discussion on the operation of the laser.
FURTHER FIELDS OF INVESTIGATION:	In addition to surveying, laser beams are used for other purposes such as surgery, industrial cutting, bar code scanning, and holography.

PROCEDURE:

There is an increasing number of commercial uses for lasers, including those in the surveying industry. Surveyors use laser beams to align pipelines, hang ceilings, level sport grounds, check elevations, and for other conventional measurements. Lasers can provide greater accuracy, perform for longer distances and save time for the surveyor.

In this lab, you will measure a distance using a laser and the properties of reflection and refraction. You will use an oscilloscope to measure the time it will take for the beam to travel from one photodetector to another. Using this time measurement and the known speed of light, you can compute the distance travelled. The apparatus you will use is a simulation of the process inherent to surveying equipment.

Description: A beam splitter deflects half of the outgoing light and directs it through a lens to one photodetector. The remaining light travels across the room to a front surface mirror and then back through a lens focusing on the second photodetector.

1. Follow the manufacturer's setup apparatus to measure the speed of light. Use a known distance of 20 m or greater.

2. The time for the light to travel from one photodetector to the other is measured by examining the phase lag of the sine waves shown on the oscilloscope. Sketch what you see on the oscilloscope (see Figure M-11-1, "Oscilloscope Grid A").

   Record the time. ___________

3. Using the relationship d = rt, calculate the speed of light.

   Speed of light = ___________

4. Knowing that the speed of light through any one medium remains constant, go into the hallway to measure an unknown distance.

5. Sketch the screen of the oscilloscope on Figure M-11-2, "Oscilloscope Grid B."

   Record the time. ___________

6. Using d = rt and your calculated value for the speed of light, calculate the distance.

   d = ___________

7. Check the result with a tape measure or a contractor's wheel.

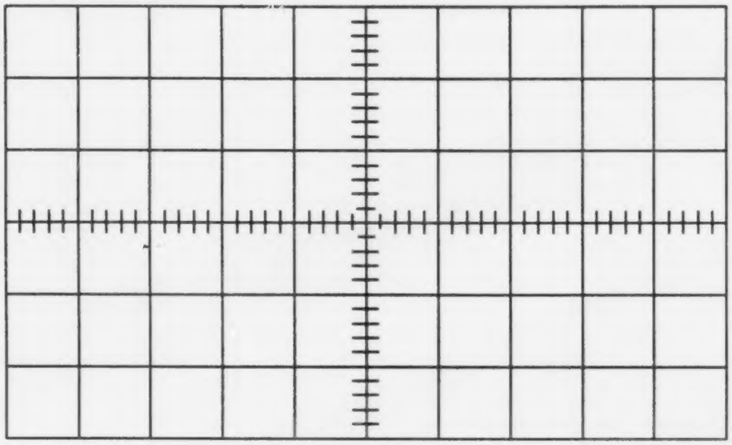


Figure M-11-1

Oscilloscope Grid A

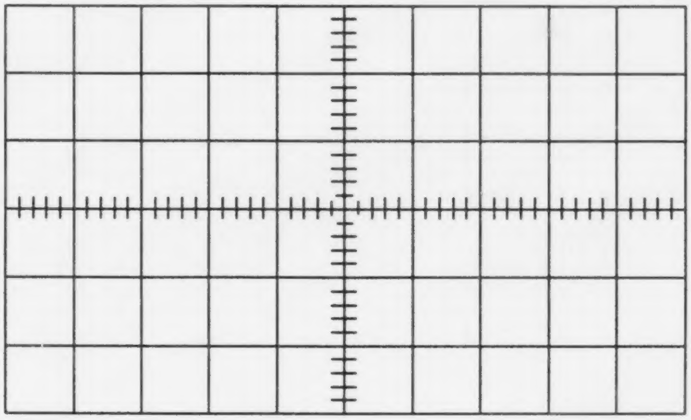


Figure M-11-2

Oscilloscope Grid B

ANTICIPATED PROBLEMS:	The activity must be performed in a dark area where there is little vibration. With large distances, it doesn't take much to throw off the laser beam.
METHODS OF EVALUATION:	Lab results Follow-up discussion Answers to student questions
FOLLOW-UP ACTIVITIES:	Contact local surveyor to demonstrate laser surveying equipment to students. Use a non-electronic device to do a surveying activity with the students, e.g., map out a baseball diamond and measure the height of the pitcher's mound.
REFERENCES, RESOURCES, VENDORS:	Speed of Light/Laser Video Kit Vendor: Metrologic P.O. Box 307 Bellmawr, NJ 08099 (609) 228-8100

POST-LAB QUESTIONS: LASER SURVEY

1. How do the "laser" results compare to the "tape measure" results?

2. Why is a front surface mirror needed for this experiment? Could the same measurements be made with a standard mirror?

3. Give two examples of the use of lasers in industry.

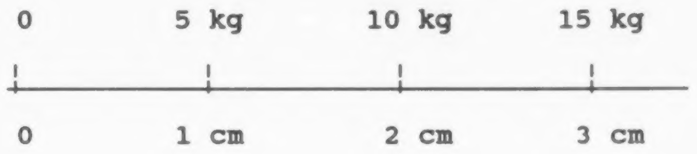
4. What is the difference between reflection and refraction of light? Where was each used in this activity?

LASER SURVEY MATHEMATICS WORKSHEET

Interpreting Scale Drawings

A scale drawing is either smaller or larger than the real object it represents. Road maps and blueprints are examples of scale drawings.

The scale of a drawing or diagram is usually a ratio of length units to the units of another quantity. The following example shows a scale in which 1 cm represents 5 kg.



1 cm = 2 kg

The conversion facts are written as ratios and dimensional analysis can be used to convert from one unit to another. For example, using the map scale 1 in = 50 miles, find the distance represented by 2.5 in.

$$2.5 \text{ in} \times \frac{50 \text{ mi}}{1 \text{ in}} = 125 \text{ mi}$$

1. Using a scale of 1 in = 75 km, determine the length this line segment represents in km.

   ____

   a. Measure the line in inches.

      Length = __________ in

   b. Convert this quantity to kilometers.

338

Using this knowledge of scale and the drawing of the house (see Figure M-11-3, "House"), answer the following questions:

2. What is the width, in feet, of the garage door?

3. In this particular neighborhood, a building must be set at least 10 feet from the lot line. What is the minimum width of a lot needed for this house?

4. Measure and calculate the pitch (slope) of the roof.

5. The square footage of a room's windows must be 10% of the floor area of a room.

    a. Measure the length and width of one of the windows above the garage. Convert these measurements to feet.

    b. Calculate the area of the window in square feet. (A = l x w)

    c. Calculate the minimum footage of the bedroom with this window.

6. The owners of the house want to plant a tree in their yard to help shade the living room. Draw a 10' tree on the right-hand side of the house.

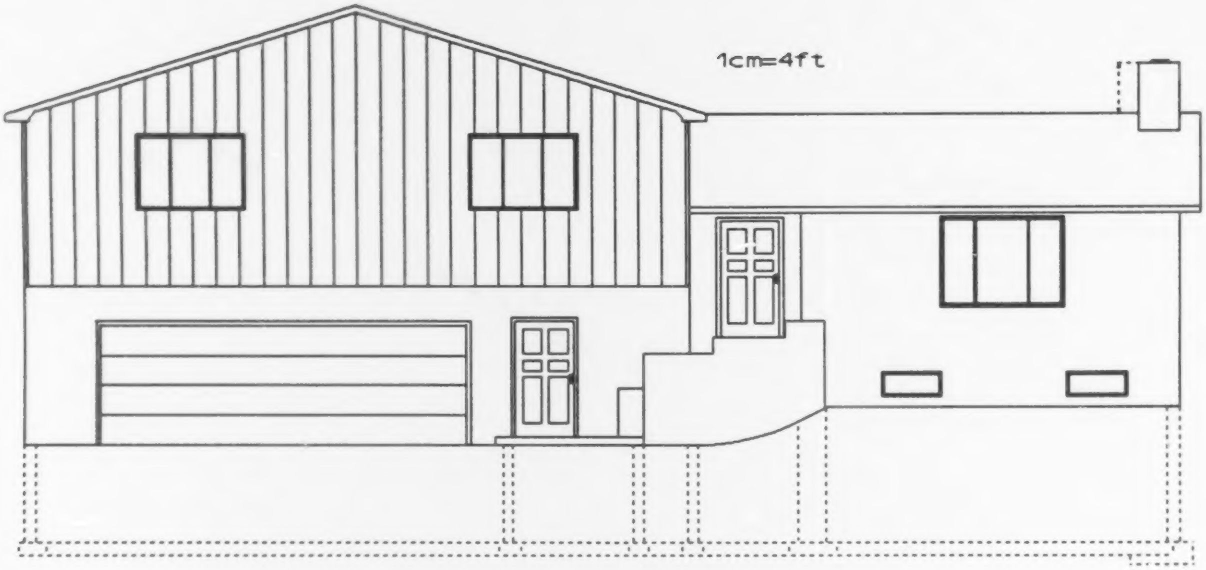


Figure M-11-3

House

ACTIVITY 12: POWER TOOLS

TECHNOLOGICAL FRAMEWORK: In industry, there is a need to have the proper tool to do a specific job. This is necessary to insure quality, cost effectiveness, and safety.

In this activity, the students will survey a variety of power tools and examine their differences with respect to speed and power transfer.

PURPOSE: To study speed and pulley ratios using technology shop equipment.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--frequency/period, angular motion, linear motion, simple machines

Mathematics--ratios, radian measure, rate, circumference, slope

Technology--speed control and transfer of power via pulley drives

PRE-REQUISITES:

Average speed as a rate of change of distance

Average acceleration as a rate of change of speed

Frequency as it applies to the operation of a stroboscope

The relationship between frequency and period

MATERIALS, EQUIPMENT, APPARATUS:

- Band saw
- Jig saw
- Fixed speed drill press/sander
- Variable speed drill press
- Stroboscope
- Meter stick
- Safety goggles for all students
- Caliper (6" capacity)

TIME FRAME: 90 minutes

TEACHING STRATEGIES:

Technology lab or Physics lab if equipment is portable

Technology teacher assisted by Physics and Mathematics teacher

TEACHING METHODOLOGY:

1. Prepare students by:
    a. Reviewing operation of the stroboscope
    b. Explaining the difference between angular and linear speed
2. Replace the cover of the band saw with a piece of clear plexiglass. Caution students about safety in the Technology lab.
3. Show the students the difference between the saws by performing similar cuts with both machines. The students will observe that cuts made with the band saw are made more quickly and have a much smoother finish. (To make a good comparison, use blades in both saws having the same number of teeth per inch.)

4. If a jig saw is inconvenient to use for the second activity, a hand-held saber saw could be substituted. Also, if a low RPM motor is not available to pull the board in front of the blade, it can be done by hand.

5. Discuss the idea of ideal rolling and the effects of slippage in drive systems. Include static and sliding friction in the discussion.

FURTHER FIELDS OF INVESTIGATION: The method of speed control by changing pulley sizes is used in a great deal of machinery from the drive on a drill press to the drive speed on the header of a combine.

Traction and friction at the point of contact between a drive belt and pulley can be compared to a tire on pavement.

PROCEDURE:

In the band saw portion of this activity, you will be investigating the linear speed of the blade and the angular displacement, velocity, and acceleration of the drive wheel.

The motion of the jig saw will be studied with an apparatus that will plot the movement of the blade. A mathematical analysis of the motion will be made by computing slopes.

For the fixed speed drill press, measurements will be made to see how the angular velocity of the shaft depends on the relative size of the drive and driven pulleys.

In this activity, the stroboscope will be used to help determine the frequency of the rotating objects.

Activity I: Band Saw

To find the linear speed of the band saw, there are two methods. The first makes use of the length of the blade and its frequency of revolution. When using this method, it is necessary that the drive wheels have the same diameter. Also, the blade may be difficult to strobe.

The second method uses the angular velocity and radius of the drive wheel to make the calculations.

Method 1

1. Measure the diameter (d) of the drive wheels and the distance between their centers (D).

   d = __________ m, D = __________ m

2. Calculate the length of the blade (L) by using the following formula:

   $L = \pi d + 2D$

   The length of the blade (L) = __________ m

3. Use a stroboscope to measure the frequency (f) of the blade.

   f = __________ rev/s

4. Determine the period (T) of the blade from the frequency by using the formula:

   T = 1/f

   The period of the blade (T) = __________ s

5. Calculate the linear speed (V) of the band saw blade by using the formula:

   V = L/T

   The linear speed of the blade (V) =

   ___________ m/s

Method 2

1. Measure the frequency of the drive wheel carrying the blade. Note that because the wheel turns through one complete revolution between each flash, the strobe frequency reading can be reported in either flashes/s or rev/s.

   Frequency = __________ rev/s

   This frequency is the same as the angular velocity (w) of the drive wheel. Convert this angular velocity to rad/s by the following formula:

   angular velocity (rad/s) = frequency (rev/s) x 6.28 (rad/rev)

   angular velocity (Ω) = __________ rad/s

2. Measure the radius of the wheel that was strobed.

   radius = _________ m

3. Calculate the linear speed (V) of the blade. Use values from (1) and (2) above and the following formula:

   angular velocity (Ω) x radius of = Linear Speed
   (rad/s) wheel (m) (m/s)

   linear speed (V) = __________ m/s

4. In addition to calculating the linear speed of the blade, it is possible to easily find the angular acceleration of the drive wheel as it stops. With the machine running at full speed, turn off the power and time how long it takes the saw blade to come to a full stop.

   time (t) = __________ s

5. Calculate the angular acceleration (α) of the wheel using the following formula:

   $\alpha = (\Omega_f - \Omega_i)/t$ where Ω_f and Ω_i represent final and initial velocities

   angular acceleration (α) = _________ rad/s^2

6. Calculate the angular displacement (θ) of the drive wheel as it slows down and stops. Use the formula:

   $\theta = \Omega_f t + 1/2\ \alpha\ t^2$

   angular displacement (θ) = _________ radians

Activity II: Jig Saw

1. Measure the frequency of the jig saw by strobing the screw nut holding the blade.

   frequency = __________ flashes/s

2. Unplug the tool and connect a marker to the blade. Operate the blade at a slow but constant rate by connecting the shaft to a variable speed drill or a low RPM motor.

3. Attach a piece of graph paper to a light-weight board. Make two vertical reference lines on the paper 20 cm apart.

4. Use a second low RPM motor to pull the board past the moving marker. Time how long it takes for the marker to pass between the reference lines.

   time between lines = __________ s

5. The pattern drawn on the graph paper should be that of a sine wave. It shows the displacement of the blade as time changes. Prepare to analyze the velocity of the blade by calibrating time on a horizontal axis drawn midway between the crests and troughs of the curve.

   a. Divide the 20 cm by the time it took to move that distance.

   b. If, for example, it takes 4.0 s for the marker to move between the reference lines, the rate at which the board is moving would be 20 cm/4.0 s or 5.0 cm/s. This also means that every 5.0 cm of paper represents one second of time. After calculating the rate, divide the horizontal axis into 1.0 second intervals.

6. Draw a vertical axis at the first reference line. Mark off 1.0 cm divisions on the axis.

7. Calculate the slope of lines drawn tangent to the following points:

   a. At a crest

   b. At a trough

   c. At a point where the curve crosses the horizontal axis

   d. At a point midway between the axis and a trough

8. Note that the units from the calculations of slope are cm/s. The slope of a displacement versus time graph represents the velocity of the object at a given time. Looking at the slope values and the curve on the paper, describe the motion of the blade in terms of its velocity.

Activity III: Fixed Speed Drill Press

A fixed speed drill press has its speed controlled by pulley size. There are two sets of pulleys in a stacked arrangement; one set is the driven pulley and the other is the drive pulley. Measurements will be made to understand how pulley size affects speed.

1. Starting at the top of the driven pulley stack, measure the diameter of each pulley and record the value in Figure M-12-1, "Fixed Speed Drill Press Data."
2. Repeat the measuring process for the drive pulleys and record.
3. Compute the ratio of the diameters, driven pulley to drive pulley, and record in Figure M-12-1.
4. Strobe the shaft to find angular speed in revolutions per second.
5. Graph angular speed vs. pulley ratio.

REFERENCES, RESOURCES, VENDORS:	United Medical Center Diagnostic Ultra Sound Department 501 Tenth Ave. Moline, IL 61265 or: local hospital
	Moline Chiropractic Clinic 4300 12th Ave. Moline, IL 61265 or: local chiropractic clinic
	Swen Sonic Corporation 960 Rolff St. Davenport, IA 52802 (309) 322-0144
	Quad City Testing Lab N. Brady St. Industrial Park Davenport, IA 52806 (309) 391-8500
	EPRI NDE Center

DATA TABLE

DRIVEN PULLEY (INCHES) | DRIVE PULLEY (INCHES) | RATIO driven/drive | ANGULAR SPEED (rpm)

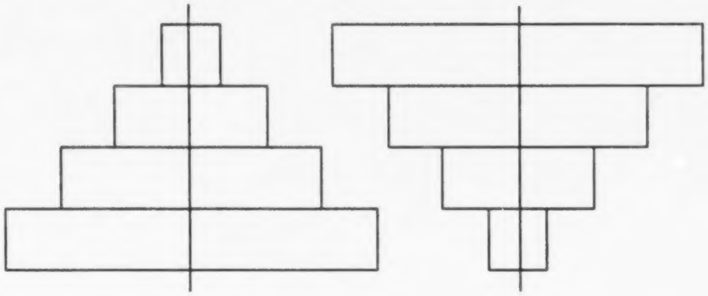


Figure M-12-1

Fixed Speed Drill Press Data

ANTICIPATED PROBLEMS:	Students may have difficulty strobing the band saw blade.
METHODS OF EVALUATION:	Answers to questions Post-lab discussion
FOLLOW-UP ACTIVITIES:	Using a variable speed drill press, remove the casing from the pulleys and run the machine, observing the changing pulley diameter. Explain that the dial allows the operator to change the diameter of the driven pulley and the drive pulley automatically changes to correct diameter as it is spring-loaded.
REFERENCES, RESOURCES, VENDORS:	Local hardware store

POST-LAB QUESTIONS

1. Compare the blade motion of the bandsaw and the jig saw. How does the motion of the blade influence the type of cutting they perform.

2. Examine the pulley system from the motor to the blade attachments on the band saw and jig saw. How are the machines similar and where do they differ?

3. From the fixed speed drill press graph, what is the relationship between angular speed and pulley ratio?

4. List other mechanical devices which depend on pulleys.

POWER TOOLS MATHEMATICS WORKSHEET

Rotational Measure: Degrees, Radians, and Revolutions

The amount an object rotates can be measured in revolutions, degrees, or radians. A revolution is one complete turn. The size of a degree can be determined by dividing a circle into 360 equal pieces or degrees. The radian, as a unit of rotational measure, can be derived by wrapping a number line around a circle of radius one unit. See Figure M-12-2, "Unit Circle."

Since the circumference is $2\pi r$, the number line will reach $2\pi(1)$ units or approximately 6.28 units around the circle. So, a measuring system of radians divides a circle into slightly more than six parts.

Rotational measurements given in one of these units can be converted to another unit, given the following conversion facts (see Figure M-12-3, "1 Radian"):

1 radian = 57.3°

1 revolution = 360°

1 revolution = 2π radians

The following problems will be used to illustrate these conversions:

1. Convert degrees to radian measure and radian measure to degrees.

$$62^\circ \times \frac{1\text{ rad}}{57.3^\circ} = 1.1\text{ rad}$$

(a) 105° x _____ = _____ rad

(b) 243° x _____ = _____ rad

(c) 34.5° x _____ = _____ rad

$$5.0 \text{ rad} \times \frac{57.3^\circ}{1 \text{ rad}} = 290^\circ$$

(d) 3.2 rad x _____ = _____°

(e) 1.25 rad x _____ = _____°

(f) 0.5 rad x _____ = _____°

2. Convert revolutions to radian measure and radian measure to revolutions.

$$3.0 \text{ rev} \times \frac{2\pi \text{ rad}}{1 \text{ rev}} = 19 \text{ rad}$$

(a) 1.4 rev x _____ = _____ rad

(b) 0.8 rev x _____ = _____ rad

(c) 2.6 rev x _____ = _____ rad

$$15 \text{ rad} \times \frac{1 \text{ rev}}{2\pi \text{ rad}} = 2.4 \text{ rev}$$

(d) 3.0 rad x _____ = _____ rev

(e) 11 rad x _____ = _____ rev

(f) 6.7 rad x _____ = _____ rev

Another common conversion is done between rev/min and rad/sec.

3. Convert rev/min to rad/sec and vice versa.

$$1{,}540 \frac{\text{rev}}{\text{min}} \times \frac{2\pi \text{ rad}}{1 \text{ rev}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 161 \frac{\text{rad}}{\text{sec}}$$

$$325 \frac{\text{rad}}{\text{sec}} \times \frac{1 \text{ rev}}{2\pi \text{ rad}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 3.10 \times 10^3 \frac{\text{rev}}{\text{min}}$$

(a) $1{,}200 \frac{\text{rev}}{\text{min}}$ x _____ x _____ = _____ $\frac{\text{rad}}{\text{sec}}$

(b) $548 \frac{\text{rev}}{\text{min}}$ x _____ x _____ = _____ $\frac{\text{rad}}{\text{sec}}$

(c) $458\ \frac{\text{rev}}{\text{sec}} \times \underline{\hspace{2em}} \times \underline{\hspace{2em}} = \underline{\hspace{2em}}\ \frac{\text{rad}}{\text{min}}$

(d) $220\ \frac{\text{rev}}{\text{sec}} \times \underline{\hspace{2em}} \times \underline{\hspace{2em}} = \underline{\hspace{2em}}\ \frac{\text{rad}}{\text{min}}$

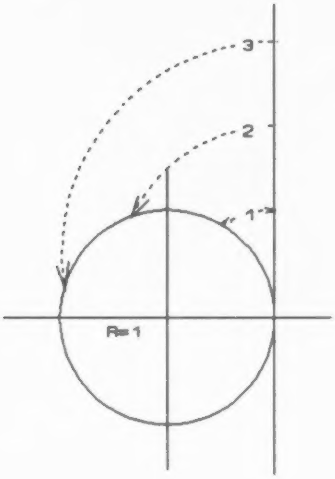


Figure M-12-2

Unit Circle

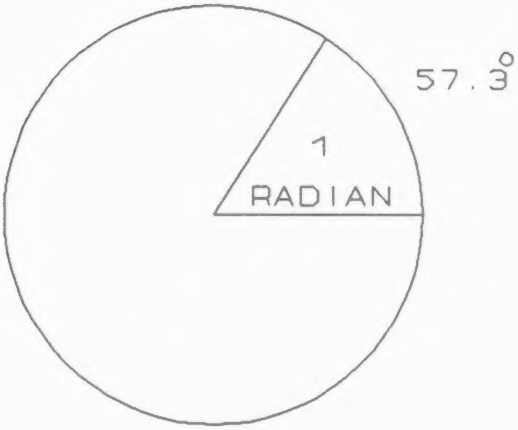


Figure M-12-3

1 Radian

ACTIVITY 13: ULTRASOUND

TECHNOLOGICAL FRAMEWORK:

When treating damaged muscle tissue, therapists try to aid healing by increasing the blood circulation through the area. One method of doing this is by the application of heat. Ultrasound is one tool used for this purpose. Energy from the high frequency sound waves is transferred to the tissues through which they pass. By this method, the therapist is better able to control the location, depth of penetration, intensity, and duration of the treatment.

In this activity, students will investigate the heat transferred to water from an ultrasound unit.

PURPOSE:

To study the relationship between frequency and generated heat using ultrasonic waves.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--properties of waves, power, heat transfer, intensity

Mathematics--graphing

Technology--ultrasound, quartz crystal oscillator

PRE-REQUISITES:

Properties of waves
Graphing

MATERIALS, EQUIPMENT, APPARATUS:
Therapeutic ultrasound apparatus
Large styrofoam cup
Digital thermometer of computer interfaced thermocouple
Water
Timing device

TIME FRAME: 45 minutes

TEACHING STRATEGIES:
Physics or Technology instructor
Mathematics instructor to aid with data analysis
Performed in Physics/Technology lab or athletic training room

TEACHING METHODOLOGY:

1. Conduct a class discussion on the general properties of waves. Be sure to include frequency and energy in the discussion.

2. Give a brief explanation of how the ultrasound equipment generates the sound wave used in therapy. (It makes use of a quartz crystal. When a voltage is placed across the crystal, it sets up an ultrasonic vibration. It is termed "ultra" because its frequency is beyond an audible range.)

3. Have students aid in the activity. Caution: Ultrasound is an energy source and must be treated respectfully. DO NOT apply this device over the following areas:

   malignant tumors
   post-operative areas
   pregnant uterus
   heart
   metal implants
   regions of impaired sensation
   epiphysis of growing bone
   reproductive organs
   eyeball
   brain area of the spinal cord
   acute infections
   areas of inadequate circulation

4. This form of ultrasound is known as "therapeutic" ultrasound. In the follow-up discussion, be sure to mention the other uses for ultrasound.

FURTHER FIELDS OF INVESTIGATION:

Uses for ultrasound in addition to therapy include:

Diagnostic--internal structure imaging, echocardiography, echocephalography, Doppler blood flow, fetal scan

Surgical--tissue destruction due to thermal effects

Industry also makes use of a form of diagnostic ultrasound to do testing for stress fractures in metal.

Ultrasonic waves are also used to clean parts.

PROCEDURE: A few of the uses for ultrasound today include: therapeutic ultrasound, diagnostic ultrasound, and ultrasonic testing.

Therapeutic ultrasound is used to treat sprained muscles through the application of heat.

Ultrasound used for medical diagnosis produces a visual image of internal structures. This is accomplished by sending short pulses of ultrasound into the body and using reflections received from various structures to form visualizations of those structures.

Similar to diagnostic ultrasound, ultrasonic testing is used for measurement. This type of testing can determine the thickness of pipe. For example, it has been used on the Alaskan pipeline to check for erosion of the pipe wall. This allows engineers to determine potential leaks without uncovering the pipeline.

In this activity, you will use a therapeutic ultrasound device to study how changing intensity levels produces a change in temperature.

1. Fill a styrofoam cup with 200 ml of cold water.
2. Place the temperature sensor in the cup and record the initial temperature of the water in Table M-13-1, "Ultrasound Data."
3. Place the ultrasonic generator in the water.
4. Set the ultrasound at 5 w/cm^2 and leave it in the water for four minutes. Record the final temperature of the water.
5. Replace the water and check its initial temperature before each trial. Repeat step 4 using 10, 15, and 20 w/cm^2.
6. Calculate the change in temperature for each trial.

7. Calculate the heat which was transferred to the water by the ultrasound by using the formula $H = m c\Delta T$, where H is heat, m is the mass of the water, c is the specific heat of the water, and ΔT is the change in temperature of the water.

8. Graph "Change in Temperature" versus Intensity for the instrument.

Table M-13-1

Ultrasound Data

Intensity (w/cm^2)	Initial Temperature (°C)	Final Temperature (°C)	Change in Temperature (°C)	Heat (calories)
5				
10				
15				
20				

ANTICIPATED PROBLEMS:

If your school does not have its own ultrasound unit in the PE department, you may need to contact a local hospital or chiropractor for a used unit, or you may be able to make arrangements to borrow a small portable unit from a chiropractor on the day that his/her office is closed.

Be sure to start with cool water for each trial. If the same water sample is continually heated, it may be found that the temperature changes decrease at around 40°C.

METHODS OF EVALUATION:

Post-lab discussion

FOLLOW-UP ACTIVITIES:

Arrange an after-school field trip to a local hospital to view their diagnostic ultrasound equipment.

Visit a local industry which makes use of ultrasound.

Expand the discussion of the resonant vibration of the quartz crystal oscillator to include other applications of resonance such as tuning forks, musical instruments, electric circuits, molecular vibrations, microwave cavities, tuning circuits and filters, etc.

View the video "Ultrasonic Testing," a part of the mini-course on non-destructive testing available from EPRI NDE Center.

Examine other forms of non-destructive testing using liquid penetrant, radiographics, magnetic particles, and eddy currents.

POST-LAB QUESTIONS: ULTRASOUND

1. What is ultra sound?

2. What is the wavelength of ultrasound waves?

3. Why is the ultrasound able to change the temperature of the water?

4. What effect does the ultrasonic intensity have on the change in temperature?

ULTRASOUND MATHEMATICS WORKSHEET

Heat Transfer

The heat lost or gained by a given substance can be calculated using the formula:

$$H = mc\Delta T$$

where: H = heat gained or lost
m = mass of substance
c = specific heat
ΔT = change in temperature

Some common specific heats are listed below:

Material	Specific Heat (J/kg•K)
copper	385
iron	450
lead	130
water	4,180

The units of specific heat have been given as J/kg•K; however, the following examples use units of °C for temperature. Since $1^{\circ}C$ = 1 K, the unit of specific heat will be written: J/kg°C.

Example 1:

A 0.5 kg mass of water is heated from 22°C to 100°C. How much heat does it absorb during the heating?

$$H = mc\Delta T$$

$$H = (0.5\ kg)\ (4{,}180\ J/kg^{\circ}C)\ (100^{\circ}C - 22^{\circ}C)$$

$$H = 1.63 \times 10^{5}\ J$$

1. A 300 g block of copper is heated from 24°C to 48°C. How much heat is absorbed by the copper?

2. How much heat is absorbed by 90.0 g of water when it is heated from 30°C to 85°C?

3. A 52 kg block of iron is heated from -12°C to 160°C. How much heat does it absorb during the process?

Example 2:

The heat lost by one body is gained by another body.

$$mc\Delta T = mc\Delta T$$

An 0.5 kg block of iron at 120°C is plunged into 3 liters of water at 30°C. What is the resulting temperature of the water and iron? (1 L of water has a mass of 1 kg.)

Heat lost by the iron = Heat gained by the water

$$mc\Delta T = mc\Delta T$$

$$(0.5\ \text{kg})\ (450\text{J/kg}^\circ\text{C})\ (120^\circ\text{C} - T) = (3\ \text{kg})\ (4{,}180\ \text{J/kg}^\circ\text{C})\ (T - 30^\circ\text{C})$$

$$(225\ \text{J/}^\circ\text{C})\ (120^\circ\text{C} - T) = (12{,}540\ \text{J/}^\circ\text{C}\ (T - 30^\circ\text{C})$$

$$27{,}000\ \text{J} - (225\ \text{J/}^\circ\text{C})T = (12{,}540\ \text{J/}^\circ\text{C})\ T - 376{,}200\ \text{J}$$

$$403{,}200\ \text{J} = (12{,}765\ \text{J}^\circ\text{C})T$$

$$31.6^\circ\text{C} = T$$

The resulting temperature of the water and iron is 31.6°C.

4. A 2.0 kg block of lead heated to 160°C is transferred to 4.5 kg of water at 20°C. What is the resulting temperature of the lead and water?

LIST OF ACTIVITIES

SHEPARD HIGH SCHOOL

Inclusive Page Nos.

Activity 1 Computer Operated Lathe (CAD-CAM), Parts 1 & 2 366-373
Activity 2 Computer Operated Lathe (CAD-CAM), Part 3 374-383
Activity 3 Automated Assembly Line with Scorbot 384-392
Activity 4 Teaching Physics Concepts Using the Scorbot ER-III 393-416
Activity 5 Addition of Velocity Vectors 417-432
Activity 6 Measuring Buoyancy with a Force Transducer 433-446
Activity 7 Torque Wrench Lab 447-456
Activity 8 Computer Interfaced Thermocouple . . . 457-466

ACTIVITY 1: COMPUTER OPERATED LATHE (CAD-CAM), PARTS 1 & 2

TECHNOLOGICAL FRAMEWORK: A small manufacturer has just received a contract to make 10^6 widgets, but they must be delivered in two weeks. He also must keep a tolerance of 10^{-5} inches. He does not have the manpower to achieve this request, but he does have CAD/CAM capability. What are his options?

PURPOSE: To become familiar with a computer operated lathe and the software which operates it.

To design a small part and program the computer to use the lathe to manufacture it.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--depending when this activity is done, the following concepts may be taught or reinforced: rotational motion, angular momentum, torque, moment of inertia, centripetal force, linear to angular conversion.

Mathematics--coordinate Geometry

Technology Skills--operation of a lathe (CAM); operation and programming skills with Graphic Aided Parts Program (SpectraLIGHT-GAPP, CAD); Integration of computer design with industrial machinery; automation.

PRE-REQUISITES:

Mathematics--Cartesian Coordinate System

Tech Skills--familiarity with keyboard and mouse

Operation of CAM programs

MATERIALS, EQUIPMENT, APPARATUS:

Computer driven lathe (Apple computer)
Graphic Aided Parts Program
Metal stock (one piece per student)
Strobe light (for follow-up activity)

TIME FRAME:

Five class periods of 50 minutes each (as an ongoing project, could be done over an extended period of time)

TEACHING STRATEGIES:

Technology teacher in Technology lab supported by Physics and Mathematics teachers, and use of computer lab to design parts. Use Mathematics teacher to teach the use of the computer programs.

TEACHING METHODOLOGY:

1. Instruct the students on the use of all computer software, including SpectraLIGHT, Autosketch, and the GAPP programs.

2. Have students run "verify" program individually in computer lab using a default program from the on-screen catalog. Use this same default program with the Control program to have the students practice running the lathe.

3. Have individual student design his or her part on Autosketch.

4. Review Physics and Math concepts involved in operation of the lathe.

5. Demonstration of CAM system using SpectraCAM.

6. Have students actually make their part on SpectraLIGHT computer driven lathe.

7. Post-lab.

FURTHER FIELDS OF INVESTIGATION:

Automotive industry (design and manufacture of new products)

Aircraft industry (design and manufacture of new products)

Metal and Woodworking (design and manufacture of parts, furniture, etc.)

PROCEDURE: With this activity, you will use a computer assisted drawing program (CAD) to draw a part to be machined automatically in the computer assisted lathe (CAM). This simulates the process which takes place in modern industry today. During this process, an engineer designs a part on a computer (CAD), fully tests the part, and makes all necessary design corrections before the part is ever made. After design and testing procedures are completed, the engineer sends the design electronically to the factory where the production machines (robots) would then be programmed from the engineer's design. In an automated factory, this pre-programmed part can be produced continuously, 24 hours a day in many cases, until the particular order has been filled. The purpose of this lab activity is to introduce you to CAD-CAM procedures and to help you understand how they are used in modern industry.

Part 1

1. Load SpectraLIGHT program.
2. Main menu will appear. Load tool path verification program.
3. Verify menu will appear. Load program.
4. A default program will appear. Press the Enter key.
5. Verify menu will appear. Select factor and single step (this will show each operation line by line).
6. Keep pressing the Enter key until you see "auto scaling." Then select Yes.
7. Select the verify program. The computer screen will now show what the lathe will be doing. If there were any problems in the programming of this piece, you would see them at this point and be able to edit your program.
8. When the computer pauses at the end of the program, press the Enter key twice.

9. Go to the control program.

10. Enter (E).

11. Place your stock in the lathe chuck.

12. Bring your tool to the facing edge of the workpiece.

13. In the control menu, select Initialize.

14. Choose a new x and z position (this tells the computer where to begin). Ask your instructor for an initial x and z position.

15. Quit the initialization and exit to the control menu.

16. Go to the program; edit and run.

17. Load your default program.

18. Run your default program. The lathe will now run the program, making the piece you saw on the screen. If there is any trouble, press the space bar to cancel the operation.

19. When the program has finished, press the Enter key twice.

20. Turn off the computer and unclamp the workpiece.

Part 2

1. Load SpectraCAM program.

2. Load toolpath verification program from menu.

3. Load the "verify" program. A default program will appear.

4. Select factors and single step.

5. Select "Yes" from auto scaling.

6. Select "verify" program from menu and watch demonstration, paying attention to x and z coordinates as piece is being turned down.

7. Exit from SpectraCAM program and load Autosketch program.

8. Use Autosketch program to draw your own part.

9. Save your design to disk.

10. Load your design file into SpectraCAM program from disk.

11. Use SpectraCAM to translate your design into numerical code for lathe to read.

12. Verify your design by running it on the "verify" program, watching for any problems. If "verify" program is unable to successfully run your part, return to Autosketch for redesign.

13. If your design runs successfully, save numeric code as new file.

14. Move to Tech lab and actually machine your part.

ANTICIPATED PROBLEMS: Access to computer lab and lathe
Troubleshooting the programs

METHODS OF EVALUATION: Grade the final product (both the actual metal part and design on the computer)

FOLLOW-UP ACTIVITIES: Design a lab around the lathe to measure angular velocity (rpm, radians per minute, degrees per minute) using a strobe light and the chuck. (Calibrate the lathe's speed control.) See CAD-CAM part 3.
Integrating the lathe with the Scorbot for a fully automated assembly line.

REFERENCES, RESOURCES, VENDORS:

Light Machines Corp.
669 East Industrial Dr.
Manchester, NH 03103
(603) 625-8600

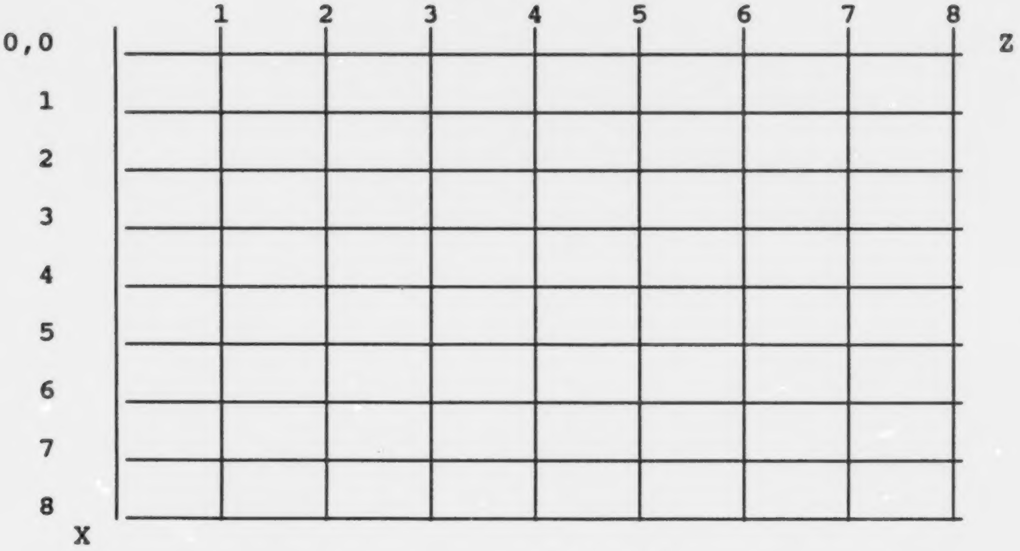
Auto Desk Inc.
2320 Marin Ship Way
Sausalito, CA 94965-9910

COMPUTER OPERATED LATHE (CAD-CAM), PART 1
MATHEMATICS WORKSHEET

Coordinate System

1. Using absolute dimensions, show the following points on the graph and connect the points.

Beginning Point	2,4
Point A	4,2
Point B	5,4
Point C	3,6
Ending Point	2,4



2. Using incremental dimensions, give the X and Z coordinates from the points above.

Beginning Point ____
Point A ____
Point B ____
Point C ____
Ending Point ____

ACTIVITY 2: COMPUTER OPERATED LATHE (CAD-CAM), PART 3

TECHNOLOGICAL FRAMEWORK:

You are on vacation and your car is weighted down with luggage and five adults. You are traveling down the highway and your tire blows out. After coming to a safe stop at the side of the road, you look in your trunk to find a tire half the size of the original. What problem could you have traveling with this spare tire at the same speed as before?

PURPOSE:

To use a computer operated lathe to teach or reinforce the Physics concepts of force, torque, angular velocity, angular momentum, and kinetic energy moment of inertia.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--depending when this activity is done, the following concepts may be taught or reinforced: rotational motion, angular momentum, torque, moment of inertia, centripetal force, linear to angular conversion.

Mathematics--coordinate geometry.

Technology--operation of a lathe (CAM); operation and programming skills with Graphic Aided Parts Program (SpectraLIGHT-GAPP; CAD); Integration of computer deisgn with industrial 9 machinery; automation.

PRE-REQUISITES:	Concepts of mass, time, length. Depending upon when this activity is taught: rotational motion, centripetal force, angular momentum torque, etc.
MATERIALS, EQUIPMENT, APPARATUS:	Computer operated lathe Variable strobe light Calipers Balance Speed control template Sample stock of varying shapes
TIME FRAME:	One to two 50-minute periods
TEACHING STRATEGIES:	The concepts of torque, angular velocity and acceleration, angular momentum, and kinetic energy moment of inertia are introduced by the Physics and Mathematics teachers. Measurements are made in the Techology lab.
TEACHING METHODOLOGY:	Review the concept of force. Define angular velocity and angular acceleration (emphasizing the labels). Define torque as an analog to linear force in angular motion. Introduce the concept of moment of inertia (emphasize that it is not unique and depends on the axis of rotation). Introduce the concept of angular momentum. Introduce or review the operation of the stroboscope effect. Have the student determine the moment of inertia of several pieces of stock that could be used with the computer operated lathe. (Give the student the formulas for a variety of simple shapes.)

Have the student calibrate the computer operated lathe using the stroboscope. (The speed control must have marks in order to reproduce the three speeds.)

Have the student calculate the angular momentum of the stock that would be used for different angular speeds.

Have the student use the strobe along with a stop clock to measure the angular acceleration of the lathe chuck from operating speed to stop. Have the student determine the torque that was necessary to accelerate the part to operating stop.

FURTHER FIELDS OF INVESTIGATION: Same as Technology portion of this lab.

PROCEDURE:

The computer operated lathe shapes a piece of stock in a predetermined way by rotating the piece on an axis of symmetry and cutting it with a cutting tool. In this activity, you will calibrate the speed control of the lathe using a stroboscope. You will determine the moment of inertia of tooling stock of different masses and dimensions. You will determine the angular speed of the stock as it is shaped. You will measure the torque exerted on the stock to accelerate it to stop from its operating speed. You will determine the linear speed of different parts of the stock and determine the centripetal force necessary to accelerate a part of the stock from operating speed to stop.

Turn the speed control to position 1. Adjust the stroboscope to "stop" the motion of the lathe chuck. Record the frequency. __________. Double the frequency of the strobe. If the chuck is again "stopped," record this new frequency. __________. Again double the frequency of the strobe. Repeat this process until the motion does not stop. The previous frequency is the frequency of the chuck.

Repeat this process for each setting on the speed control.

In all of the following, be sure to include appropriate labels (rad/s):

Position:

1. _____
2. _____
3. _____

Is the speed control linear?_____

1. Measure the diameter of each sample stock and determine its radius. Record the radius.

    A. _____
    B. _____
    C. _____
    D. _____

2. Measure the mass of each sample stock and record.

A. _____
B. _____
C. _____
D. _____

3. Using the formulas for moment of inertia, calculate the moments for each sample stock.

A. _____
B. _____
C. _____
D. _____

4. Calculate the angular momentum for each sample (using L = Iw) if the angular velocity of the sample is that of setting 3 on your speed control template. Record.

A. _____
B. _____
C. _____
D. _____

5. Calculate the linear speed of an element of mass farthest from the axes of rotation for each sample. (Use v = rW) Record.

A. _____
B. _____
C. _____
D. _____

6. Calculate the centripetal acceleration for a one gram mass at the linear speeds calculated in question #5. (Use $a = mv^2$) Record.

7. Calculate the centripetal force to cause the acceleration of the mass in #6. (Use F = ma) Record.

A. _____
B. _____
C. _____
D. _____

8. What is the origin of the centripetal force on the rotating mass of the sample? What might happen if the angular velocity were to be increased a very high value?

ANTICIPATED PROBLEMS:	Confusing the labels for the angular motion terms
METHODS OF EVALUATION:	Teacher-generated test
REFERENCES, RESOURCES, VENDORS:	Light Machines Corp. 669 East Industrial Dr. Manchester, NH 03103 (603) 625-8600 Auto Desk, Inc. 2320 Marin Ship Way Sausalito, CA 94965-9910

POST-LAB QUESTIONS: COMPUTER OPERATED LATHE (CAD-CAM), PART 3

1. What is the primary purposes of a lathe?

2. What safety device do we use when operating the lathe?

3. Explain the difference between speed and feed

4. Explain the Cartesian Coordinate System.

5. In absolute dimensioning, each point is relative to 0,0. What is incremental dimensioning.

COMPUTER OPERATED LATHE (CAD-CAM), PART 3 MATHEMATICS WORKSHEET

1. Convert the following angle measurements to radians:

   a. 45°

   b. 65°

   c. 142°

   d. 135°

   e. 68.5°

2. Convert the following angle measurements to degrees:

   a. $\pi/3$ rads

   b. 1.57 rads

   c. 8 rads

   d. 0.5 rads

   e. $\pi/12$ rads

3. Convert the following measurements to angular speed (both degrees/second and radians/second):

   a. 100 rpm

   b. 250 rpm

   c. 350 rpm

4. 0.5 rpm

5. 1.86 rpm

4. How fast is an automobile traveling in km/h if the axle is turning at 350 rpm and the tire has a radius of ...

   a. 30 cm

   b. 25 cm

   c. 35 cm

   f. 3 m

5. Calculate how fast you are moving on the surface of the earth (linearly with respect to the earth's axis of rotation) in km/h if you are standing ...

   a. at the equator

   b. in Chicago, Illinois (45° latitude)

   c. in your hometown

ACTIVITY 3: AUTOMATED ASSEMBLY LINE WITH SCORBOT

TECHNOLOGICAL FRAMEWORK: You're the manager of an automated assembly line. One of the robots breaks down, stopping the production of the entire line. What are some of your options?

PURPOSE: To introduce students to the development, operation, and purpose of an industrial assembly line.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--depending when this activity is done, the following concepts may be taught or reinforced: rotational motion, angular momentum, torque, moment of inertia, centripetal force, linear to angular conversion.

Mathematics--basic computer programming structure

Technology--the development and use of assembly lines in industry

Robotics - CAM

PRE-REQUISITES: Technology skills--knowledge of the use of assembly lines and automation in general in industry.

MATERIALS, EQUIPMENT, APPARATUS:

Scorbot-III and accompanying software
Linear slide accessory
Conveyor belt accessory
Spectralight computerized lathe
Metal stock

TIME FRAME: Five 50-minute class periods

TEACHING STRATEGIES:

Mathematics teacher introduces computer programming techniques with Scorbot

Technology teacher introduces sample assembly lines and uses in actual industry

Physics teacher assists both

TEACHING METHODOLOGY:

1. Introduce students to the varied applications of assembly lines and automation in industry.
2. Demonstrate the writing of a program for a simple assembly line, while instructing the students on the Scorbot programming language (Parts 1 and 2 of PROCEDURE).
3. Teach students simple programming structure ("go-to" statements, simple loops, if-then structure, etc.).
4. Have students develop an idea for an assembly line and turn it in for approval.
5. Students in Technology lab to actually write program to execute their idea (one group at a time).
6. Have students load program and actually run their program on the Scorbot (while explaining it to the rest of the class).

FURTHER FIELDS OF INVESTIGATION:

Automation procedures in industry such as spray painting, arc welding, handling of radioactive materials, spot welding, extracting dies from casting machines, transferring materials, assembly, and finishing.

PROCEDURE:

In the modern industrial world, many of the jobs once done manually have been taken over by robots. With this lab activity, you will be introduced to the varied applications of a robot in today's industry. In addition to designing your own assembly line on paper, you will have the opportunity to program the Scorbot to carry out your ideas, and see if they work. Part 1 of the lab is a simple exercise to introduce you to what the Scorbot is capable of doing, Part 2 introduces you to the programming language, Part 3 allows you to creatively design your own assembly, and Part 4 asks you to integrate another piece of automated equipment into your project allowing you to produce a metal part.

The purpose of this lab is to demonstrate the advantages of an automated assembly line in industry, and to allow you to try your hand at the design and programming of such a process.

Part 1 - Pick and Place

1. Robot menu will appear on screen; select Scorbot level 2 and press C.
2. Synchronize the robot first by selecting Home (#5).
3. To synchronize, select G.
4. Press ESC. You are now back to the main menu. Select #1.
5. The teach menu is used to teach the Scorbot the positions that will be part of your program. The first position you want to record is the home position which the robot should be in now. Press P and Enter. Make sure you write down the position numbers and a brief description of where that position is.
6. Move the robot arm to about 6 inches above the block you want to pick up and record this as your second position.

7. Move the robot arm so that the gripper is in position to pick up the block and record this as your third position.

8. Simply close the gripper by pressing C (this is not recorded as a new position).

9. Move the robot arm to about 6 inches above the point where you want to place it and record this as your fourth position.

10. Move the robot arm down to place the block on the table and record this as position 5.

11. Simply open the gripper by pressing O.

12. You are now ready to use the Go-To position command to test your program before actually writing it.

    a. Press G 1 and Enter.

    b. Press G 2 and Enter.

    c. Press G 3 and Enter.

    d. Press C.

    e. Press G 4 and Enter.

    f. Press G 5 and Enter.

    g. Press O.

    h. Press G 1 and Enter.

13. Now save the sequence of go-to commands you just entered by pressing ESC (which gets you back to the main menu), selecting #3 (Program Handling), selecting #1, and save by using your name as a file name.

Part 2 - Writing a Simple Program

1. Select Scorbot level 2 from the main menu. Synchronize the robot by selecting Home and then type G.

2. Press ESC. You are now back to the main menu, and you want to load the list of go-to statements you saved in Part 1, so select program handling (#3).

3. From the program handling menu, select Catalog to find the file containing your list of commands (they should be listed in a file under your name).

4. Load your file by selecting Load Program (#3) and type in the file name.

5. Return to the main menu by pressing ESC.

6. Select Edit program (#2). You are now able to actually write a program using the positions you taught the robot in Part 1 and the commands in the Edit program menu (now on the screen).

7. To create your own program, type the following:

    a. Select #1 (Go-To position); type 1 and Enter; now set the speed to "fast."

    b. Select #2 (Go-To position); type 2 and Enter; speed 5.

    c. Select #1 (Go-To position); type 3 and Enter; speed 2.

    d. Select C (Close gripper).

    e. Select #1 (Go-To position); type 4 and Enter; speed 5.

    f. Select #1 (Go-To position); type 5 and Enter; speed 2.

g. Select O (Open gripper).

h. Select #2 (Go-To position); type 1 and Enter; speed fast.

8. The program is now complete and should be saved to disk by returning to the main menu (ESC). Now select Program Handling (#3) and select #2 to save your program (type the name of your program when prompted to do so).

9. Return to the main menu to run the program (ESC).

10. Select #4 to run the program.

11. First, run your program one line at a time by selecting "single line" (#2) and type G to let the robot run. Press G for each part (line) of your program. Running your program single line is a way to check for mistakes before running the program continuously (all at once).

12. Once you have run the program one line at a time, run it single cycle (robot will go through entire program once) by selecting #2 and pressing G.

13. Finally, run your program continuously (repeat through steps an infinite number of times) by selecting #3 and press G.

14. To stop the robot from running, press the "Enter" key and the program will terminate.

Part 3 - Complex Programming

1. Design your own automated assembly line process, making sure to take into consideration purpose and practicality with the Scorbot ER III, including the use of the conveyor belt, gravity slide, and linear slide accessories.

2. Use the computer to teach your process to the robot and write a program to run the assembly line.

3. Demonstrate and explain to the rest of the class.

4. Turn in a computer printout of your program.

Part 4 - Designing an Automated Workcell

1. Using the Autosketch program, design a part to be machined on the lathe. (You may use your design from the lathe activity in order to save time.)

2. Using the procedures from the lathe lab, transfer your drawing to the SpectraLIGHT lathe.

3. Design an automated workcell that has the robot pick up a piece of material from a bin, place it in the jaws of the SpectraLIGHT lathe, run the lathe (machine the part), and place it in a bin of finished parts. (See Figure S-3-1, "Example of Assembly Line Using Scorbot on Slide--SpectraLIGHT Lathe and Conveyor.")

4. Demonstrate and explain your assembly to the class.

5. Turn in a computer printout of your program.

ANTICIPATED PROBLEMS:

Developing an efficient way to use the Technology lab (one group at a time) while keeping the rest of the class busy.

In Part 4 of this lab, the Scorbot Computer Integrated Manufacturing lab manual will be extremely helpful.

METHODS OF EVALUATION:

To evaluate the final projects for practicality, efficiency, and programming style.

FOLLOW-UP ACTIVITIES:

Field trip to an automated assembly plant.

REFERENCES, RESOURCES, VENDORS:

Eshed Robotec, Inc.
45 Wall Street
Princeton, NJ 08540

Light Machines Corp.
669 East Industrial Dr.
Manchester, NH 03103

Auto Desk, Inc.
2320 Marin Ship Way
Sausalito, CA 94965-9910

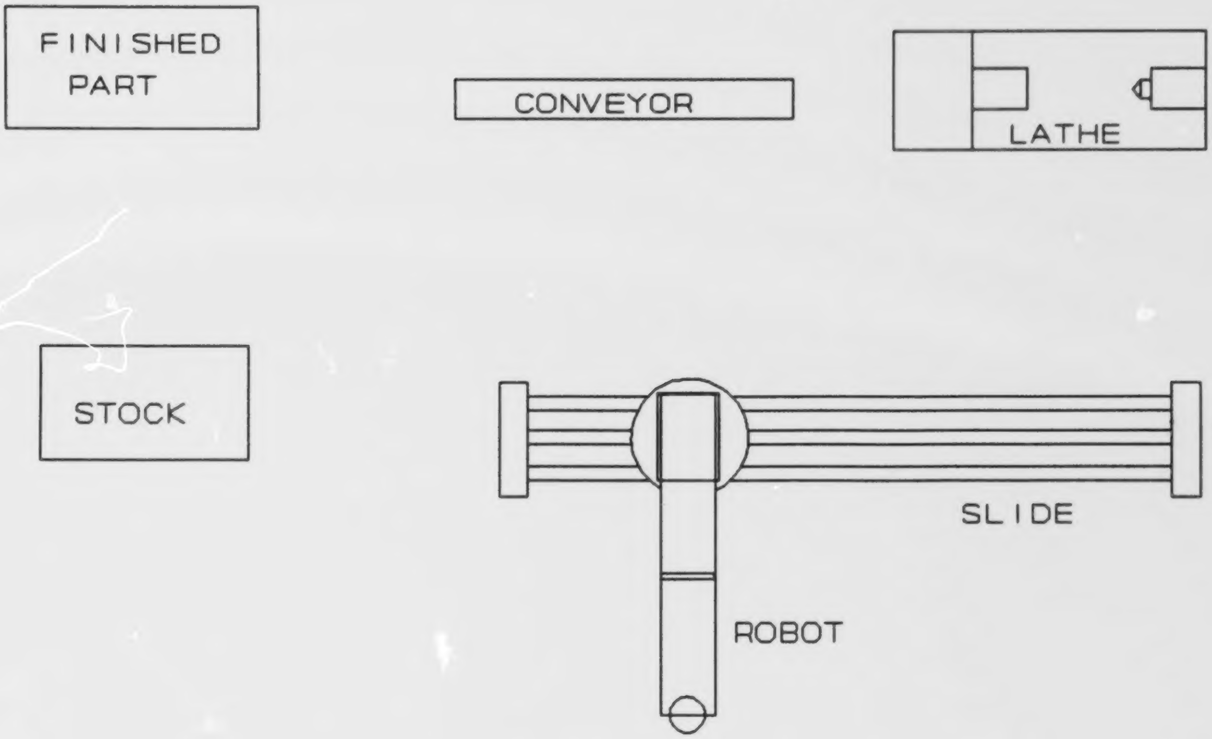

FINISHED PART
CONVEYOR
LATHE
STOCK
SLIDE
ROBOT

Figure S-3-1

Example of Assembly Line Using Scorbot on Slide--
SpectraLIGHT Lathe and Conveyor

ACTIVITY 4: TEACHING PHYSICS CONCEPTS USING THE SCORBOT ER-III

TECHNOLOGICAL FRAMEWORK: The Scorbot is a machine built with a combination of the six simple machines studied in physics. Pretend you and your lab partner are employed as engineers, and are asked to design a machine to automatically crack an egg in a mixing bowl. Use a combination of the six simple machines to design an automatic egg cracker. Compare your design to the others in the class, and decide which is the most efficient machine.

PURPOSE: To use a programmable robot to present a variety of Physics concepts.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
Work
Linear and rotational motion
Motion in 1, 2, and 3 dimensions

Mathematics:
Circumference
Three-dimensional geometry

Technology:
Operation of the Scorbot
Parts of a robot, automation

PRE-REQUISITES:	Units of measure Displacement Velocity Force and Newton's three laws
MATERIALS, EQUIPMENT, APPARATUS:	Scorbot ER-III and software IBM compatible computer Scorbot accessories, including the conveyor belt, linear slide, and gravity slide Stop watch, meter stick, protractor
TIME FRAME:	Two 50-minute periods
TEACHING STRATEGIES:	Physics teacher introduces concepts in classroom Mathematics teacher works with students on problem solving in computer lab Technology teacher demonstrates and explains the robot in Technology lab Students work in groups of four or less
TEACHING METHODOLOGY:	Review the concept of force. Introduce work as the scalar product of force and displacement. Have the student measure, using a stop watch and meter, the linear speed of the robot slide. Have the student measure the angular speed of the robot about its vertical axes, the angular speed of the robot's arm about the shoulder and elbow.

Have the student use the robot to move a known mass through three dimensions and compute the work done by the robot on the mass. Have the student time this motion with a stop watch and compute the power. (It may be beneficial to use a wattmeter during these measurements to demonstrate that most of the energy consumed does not result in work on the material moved.)

Introduce and identify the six simple machines: lever, inclined plane, pulley, screw, wheel and axle, and wedge.

Introduce the Scorbot ER-III with demonstration program included with software (see manual).

Have the students identify the simple machines that make up the Scorbot and record (tag each simple machine with letters).

FURTHER FIELDS OF INVESTIGATION: Automation procedures in industry such as spray painting, arc welding, handling of radioactive materials, spot welding, extracting dies from casting machines, transferring materials, assembly, and finishing.

PROCEDURE:

The robot gripper can move in three spatial dimensions (x, y, z). Its velocity and acceleration are determined by the individual motions of the slide, arms, and wrist. In this activity, you will measure the linear velocity of the slides and the angular velocity of the robot arms and gripper. You will also calculate the work done by the robot on a mass held by the gripper and the power developed. You will make estimates of the acceleration of the moving parts. The maximum force that the robot can exert will be measured for two orientations of the robot arm. All complex machines are actually combinations of the six simple machines. In this activity, you will identify the simple machines that are combined to construct the Scorbot ER-III robot (Detroit). The simple machines which make up the Scorbot will then be studied individually, and you will measure their lever arms, and mechanical advantages. This information will help you interpret some of the purposes of simple machines, and hopefully, help you understand how the Scorbot operates.

Motion, Work, Power

1. Measure the time for the robot to move a measured distance (approximately 1 meter) along its slide, and compute its speed. Record. __________.
2. Measure the time for the robot to rotate through a measured angle (use a protractor to measure the angle, approximately 45 degrees) about its vertical axis. Compute the angular speed in degrees/s and radians/s. Record __________, __________.
3. Repeat step 2 for the rotation of the shoulder. Record. Shoulder __________.

4. Place a known mass in the gripper with the robot at the beginning of its track. Move the mass to a new position and measure the change in the x, y, and z positions. Measure the time for the motion. Calculate the work done against the force of gravity on the mass by the robot. Calculate the power. Record __________, __________.

Simple Machine Identification

1. Identify as many simple machines as possible involved in the construction of the Scorbot, and record these on a piece of notebook paper by using the letters attached to each part of the robot.

Work Envelope

1. Measure the degree of freedom for each joint on the Scorbot using a protractor.

   Base__________________________
   Shoulder______________________
   Elbow_________________________

Lever

1. Position the robot so that the links between the shoulder, elbow, and wrist are horizontal to the floor. See Figure S-4-1, "Scorbot Extended Horizontally with Spring Scale."

2. Measure the distance from the center of the drive gear of the elbow to the end of the gripper.

3. Measure the radius of the elbow's drive gear and record on lever arm in Figure S-4-1.

4. Calculate the IMA of the link between the elbow and wrist (lever) and record on lever arm in Figure S-4-1.

5. With the Scorbot linkages still extended horizontally with the floor, remove the 2 kilogram weight from the grippers, move the wrist pitch so it is perpendicular to the floor, and secure the end of a spring scale in the grippers.

6. Adjust the shoulder so that it is possible to clamp the other end of the spring scale to the table, and clamp the spring scale down (see lever arm in Figure S-4-1).

7. Lift the shoulder up until the motor buries and record the maximum lifting force.

8. Lower the shoulder and release the spring scale from the grippers.

9. Position the Scorbot so the link between the shoulder and the elbow is still horizontal to the floor, but the link between the elbow and wrist is perpendicular to the floor along with the wrist (see lever arm in Figure S-4-2, "Scorbot Elbow Perpendicular to Floor").

10. Repeat steps 7 and 8 with Scorbot in new position and record the maximum lifting force.

Gear and Belt

1. Measure the diameter of the drive gear of the conveyor belt and record.

2. Calculate the circumference of the drive gear.

3. Make a chalk mark on the drive gear and belt.

4. Run the drive gear, counting the number of revolutions necessary to move the belt around once, and record.

5. From the information recorded above, determine the length of the belt.

Screw

1. Position the Scorbot in its home position and move it to one end of the linear slide.
2. Place a piece of tape on the screw of the linear slide at the opposite end of the robot.
3. Mark the position of the Scorbot with a piece of tape on the table.
4. Move the Scorbot at speed #1 across the table with the linear slide until the screw has rotated 25 times, keeping count with the help of the piece of tape.
5. Mark the new position of the robot with another piece of tape on the table.
6. Measure the distance the robot traveled with 25 revolutions of the screw by measuring the distance between the two pieces of tape on the table.
7. Calculate the pitch of the screw by using the formula pitch * revolutions = distance.
8. Measure the pitch of the screw directly and compare to the calculated value from #7.

ANTICIPATED PROBLEMS:	Organizing a way for laboratory groups to rotate the use of the Scorbot ER-III.
METHODS OF EVALUATION:	Grading the laboratory report for accuracy.
FOLLOW-UP ACTIVITIES:	Classic Physics labs on all these Physics concepts would be a good way to follow up these activities or to introduce them. It could also be beneficial to include some classic labs along with these activities to further illustrate the construction of the Scorbot ER-III.

REFERENCES, RESOURCES, VENDORS:

Eshed Robotec
445 Wall Street
Princeton, NJ 08540
(609) 683-4884
(800) 77ROBOT

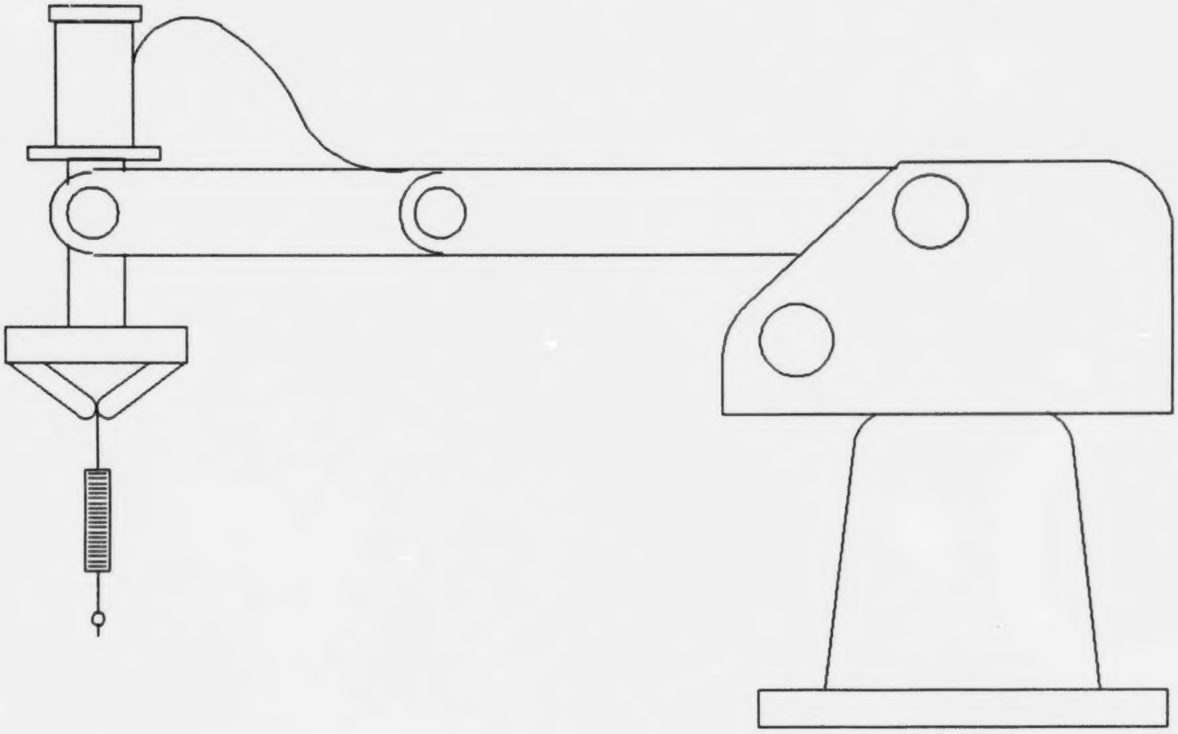


Figure S-4-1

Scorbot Extended Horizontally with Spring Scale

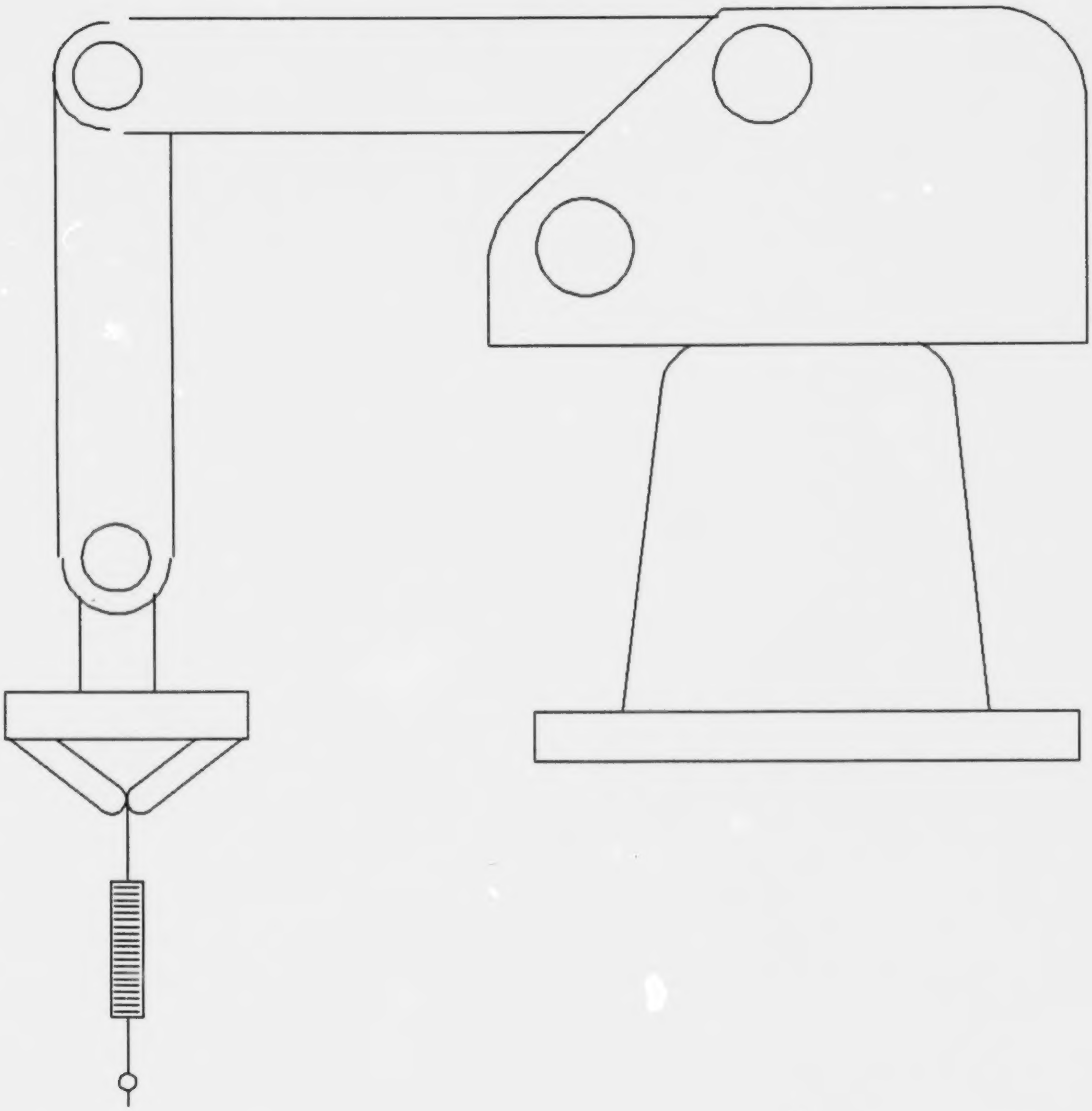


Figure S-4-2

Scorbot Elbow Perpendicular to Floor

POST-LAB QUESTIONS: SCORBOT ER-III

1. Explain the home position of the robot.
2. Name the main parts of the robot.
3. Name the simple machines you found on the robot.
4. What simple machine moved the base of the robot?
5. What simple machines are involved in the operation of the conveyor belt?

PHYS·MA·TECH
AN INTEGRATED PARTNERSHIP

SCORBOT ER-III MATHEMATICS WORKSHEET

3-Dimensional Graphing--Physics of the Scorbot

Graph the following points on the x, y, z axis. Beginning with number 5, draw a rectangular prism (as shown in the example) to help you visualize three dimensions.

1. (0, 0, 0)
2. (0, 0, 3)
3. (0, 3, 0)
4. (3, 0, 0)
5. (4, 5, 0)
6. (4, 0, 5)
7. (0, 4, 5)
8. (3, 5, 7)
9. (7, 5, 3)
10. (3, 7, 5)

Using the distance formula,

$$(d = \sqrt{x^2+y^2+z^2})$$

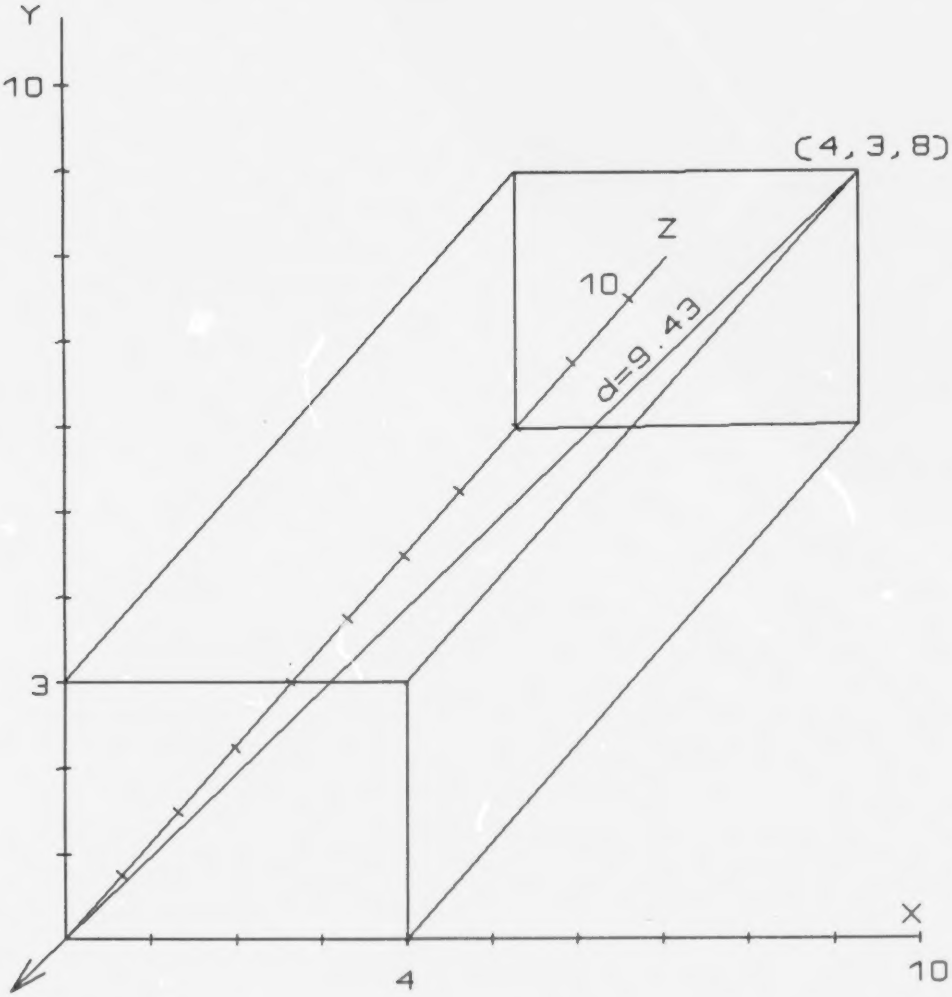
calculate the distance each point above is from the origin.

Lamb/Maras/Salabura
Shepard High School
Activity 4
Teaching Physics Concepts
Using the Scorbot ER-III

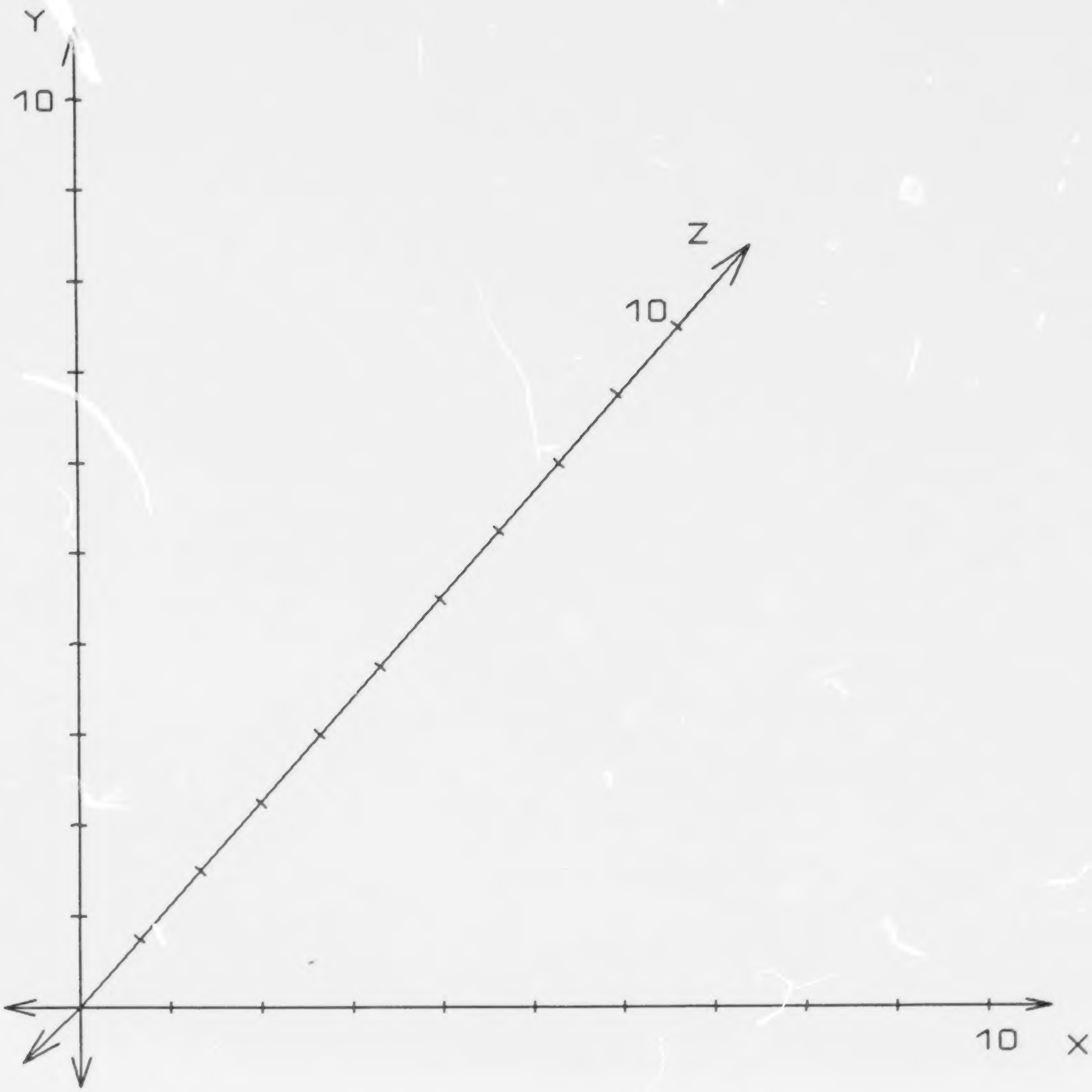
Example - Graph (4, 3, 8)

distance =

$$\sqrt{(4)^2 + (3)^2 + (8)^2} \approx 9.43$$



(1)



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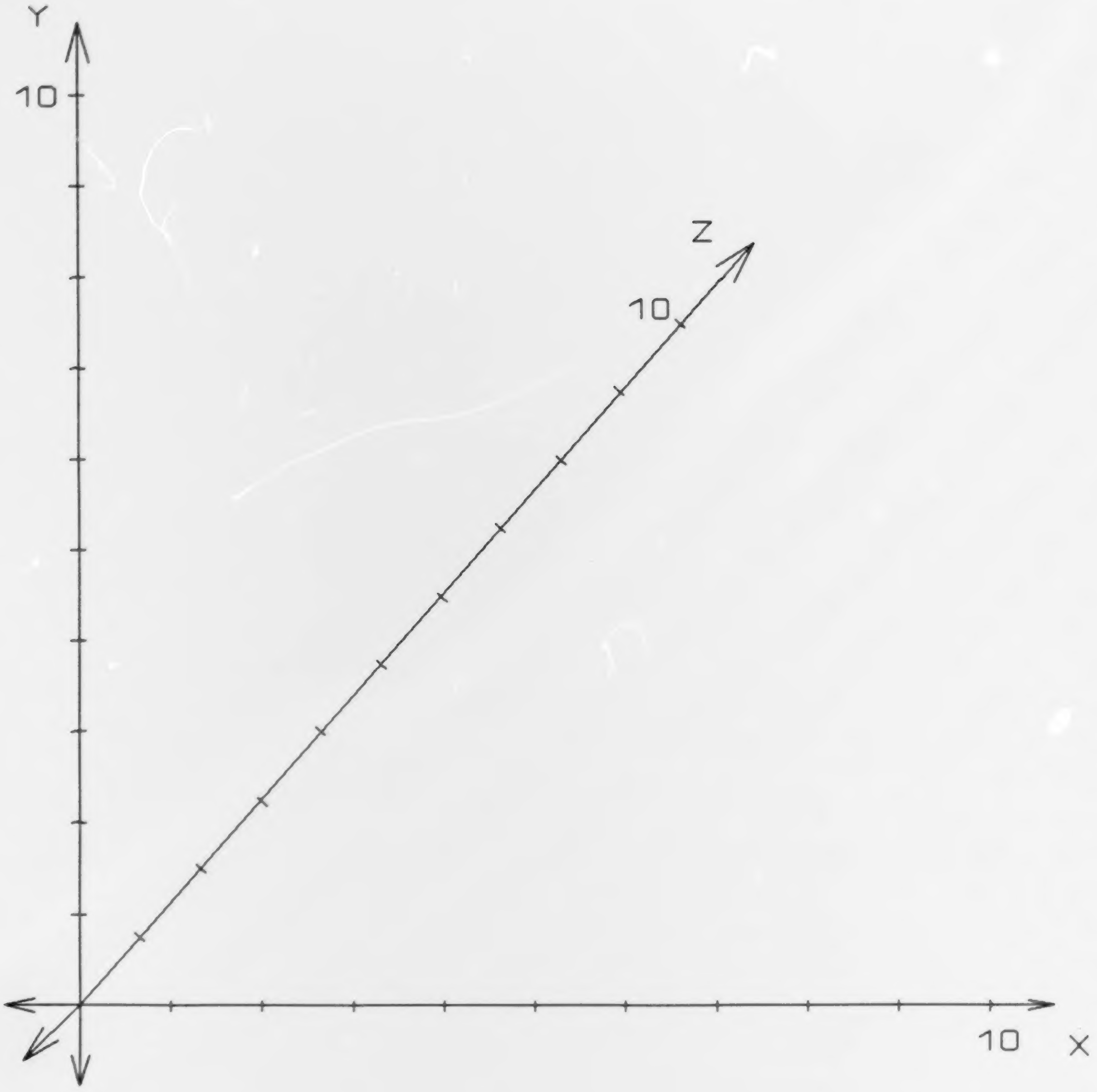

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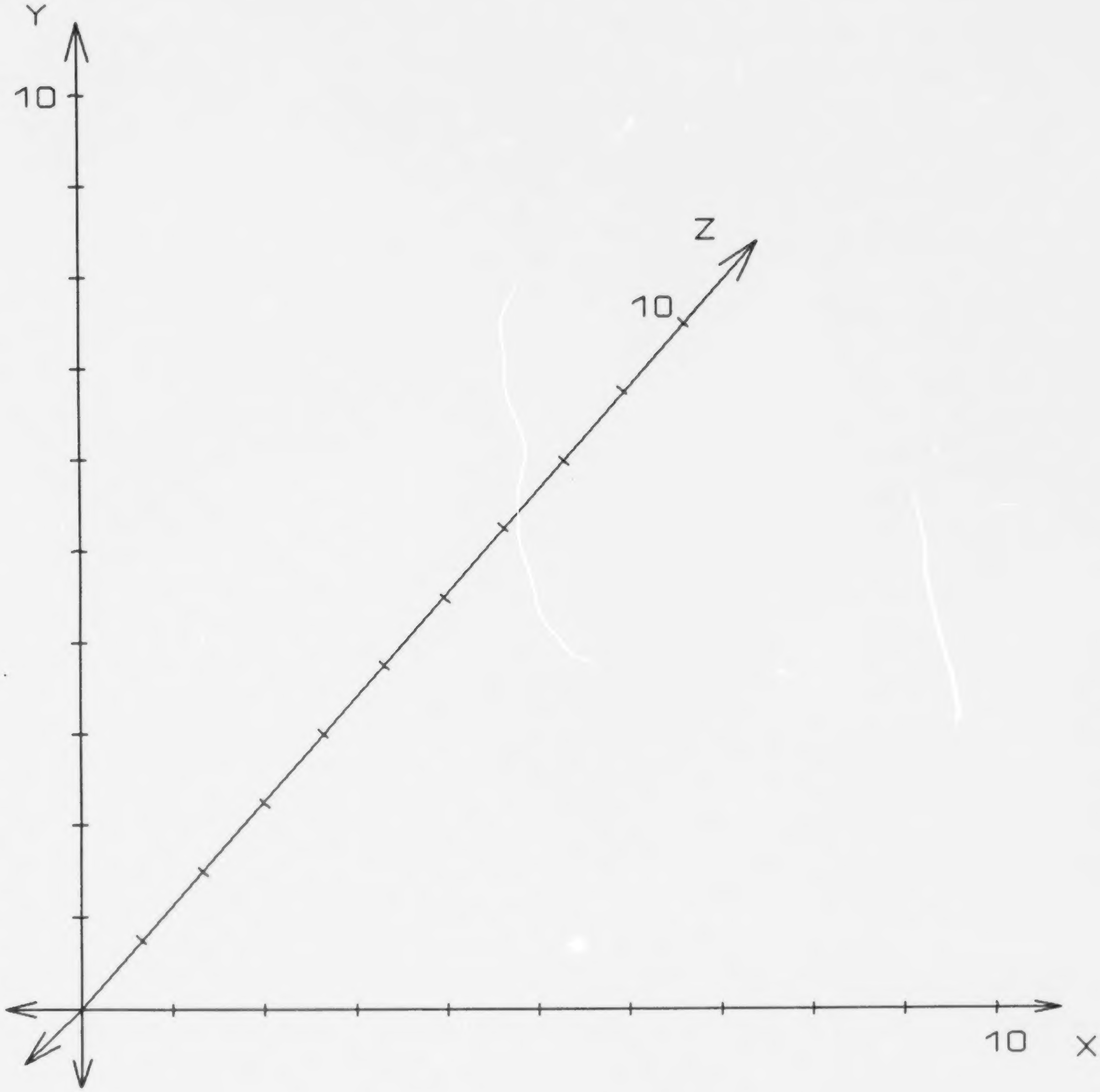

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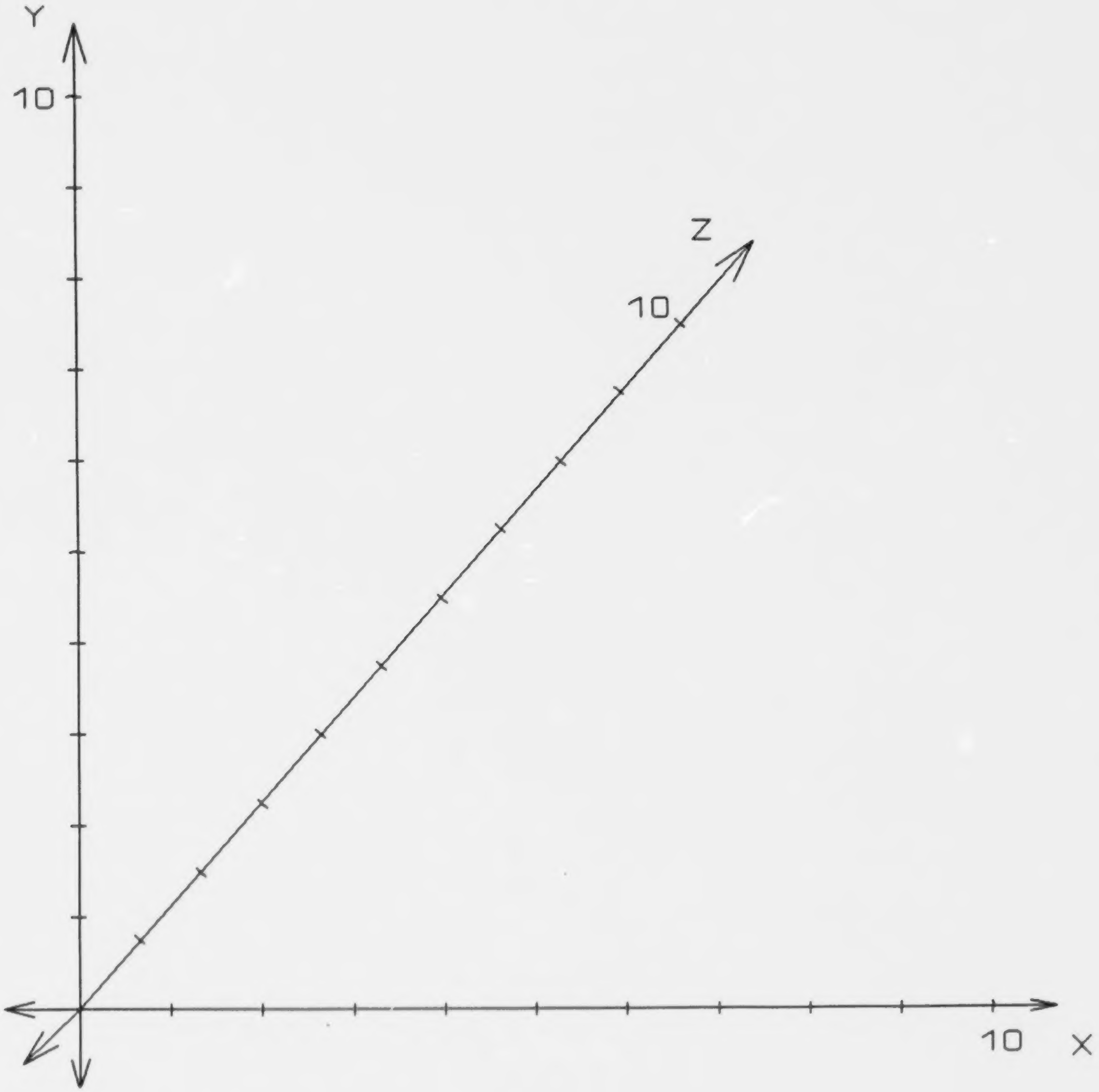
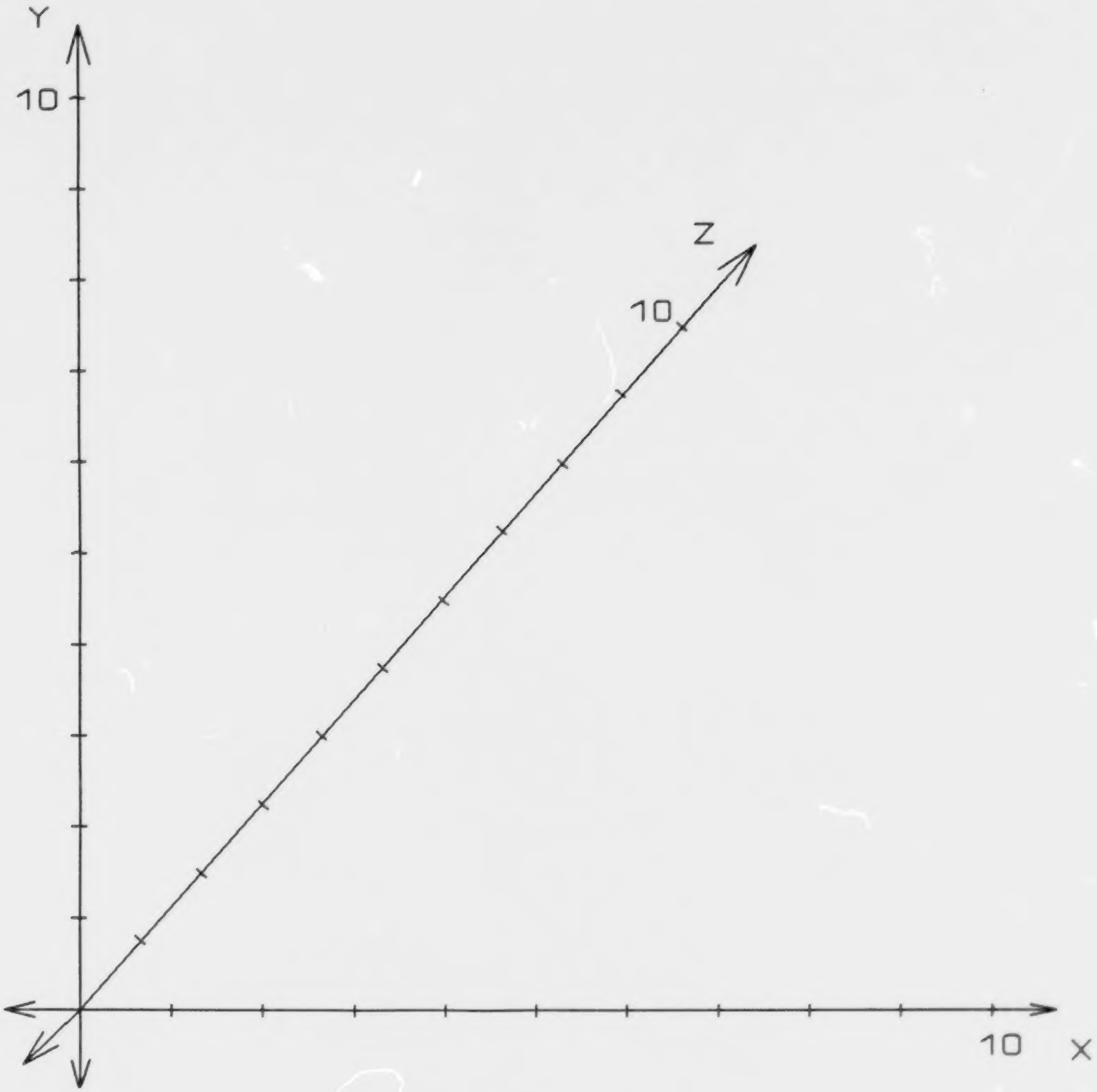


(5)



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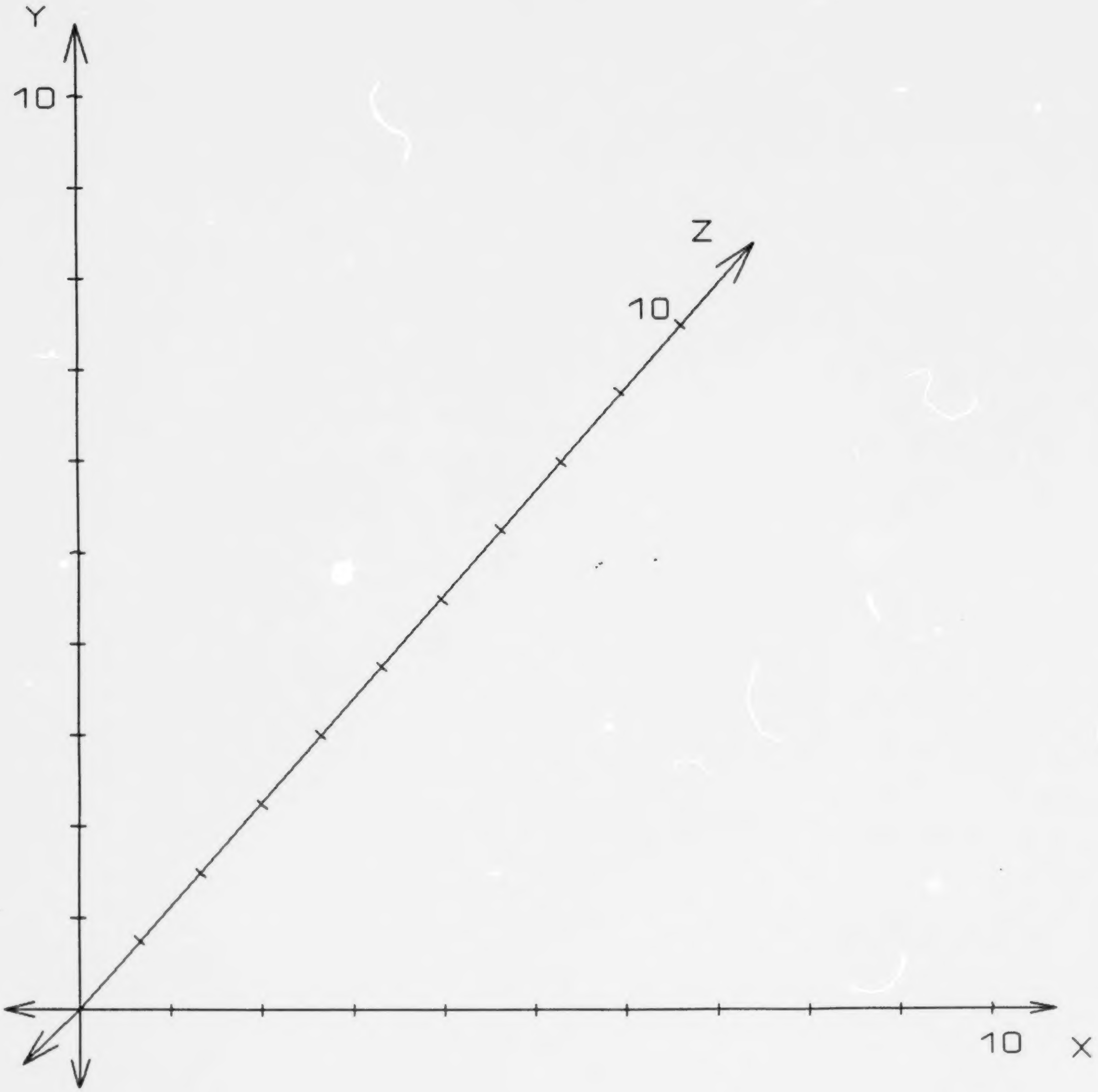

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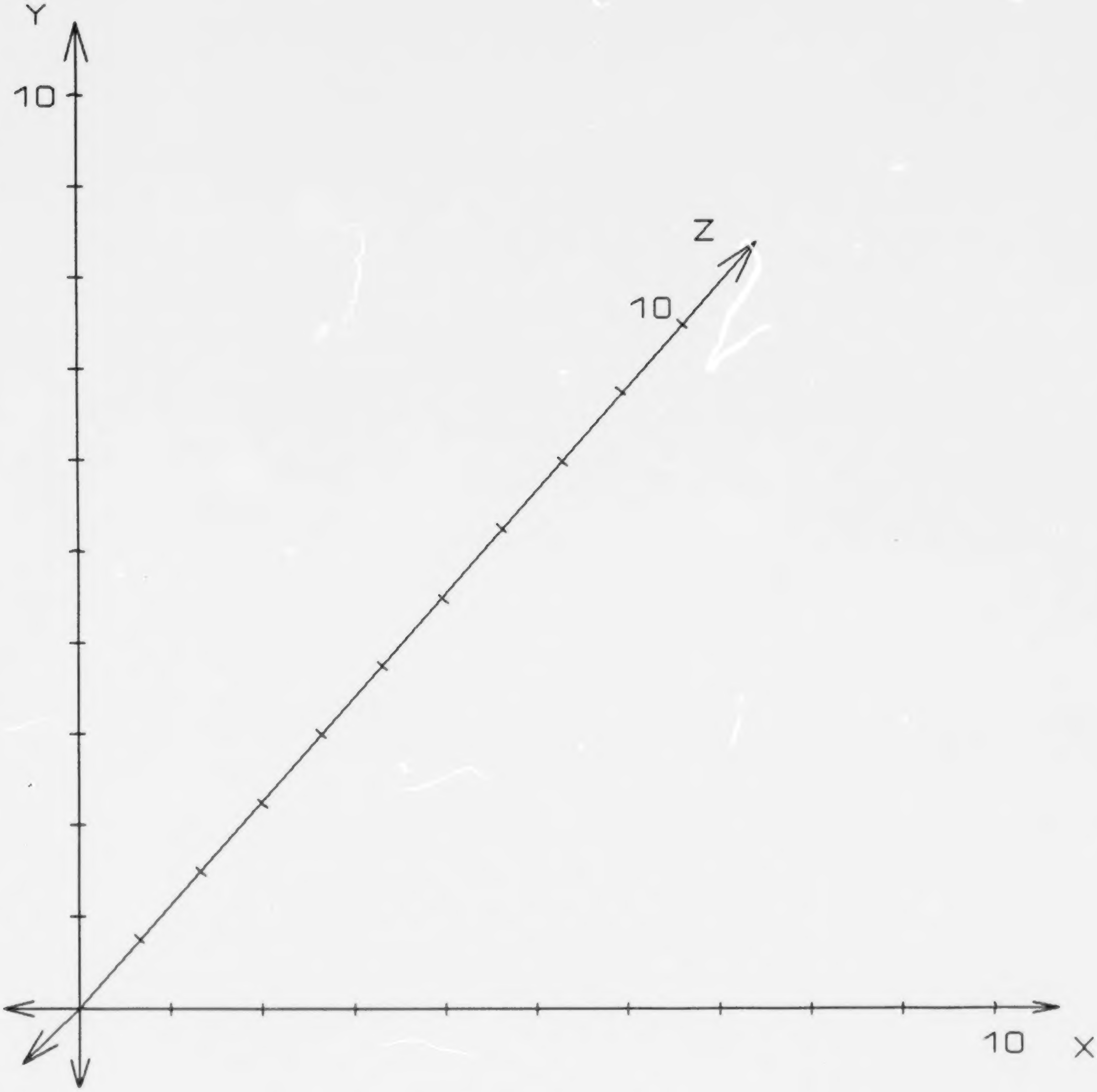

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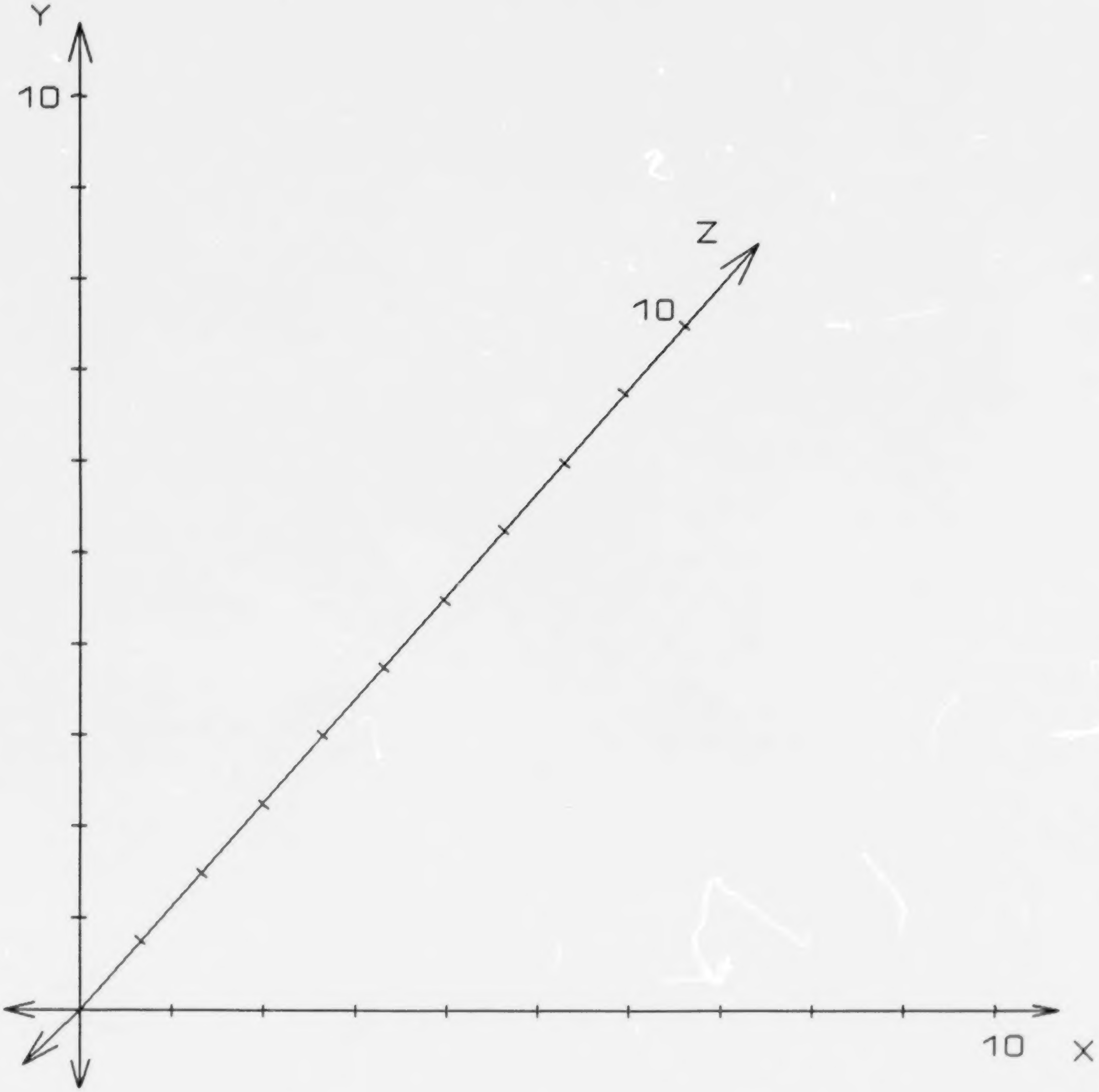

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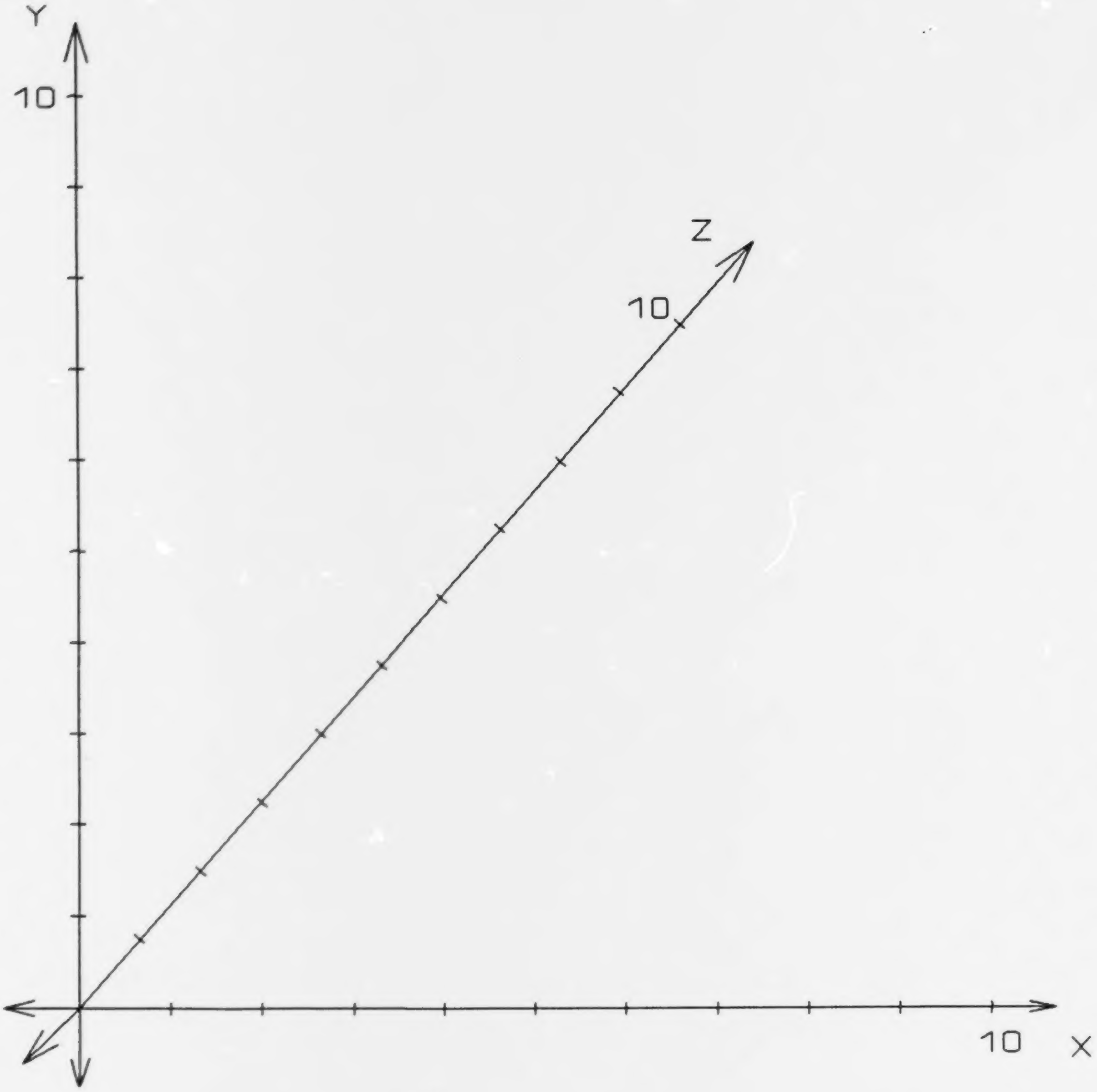

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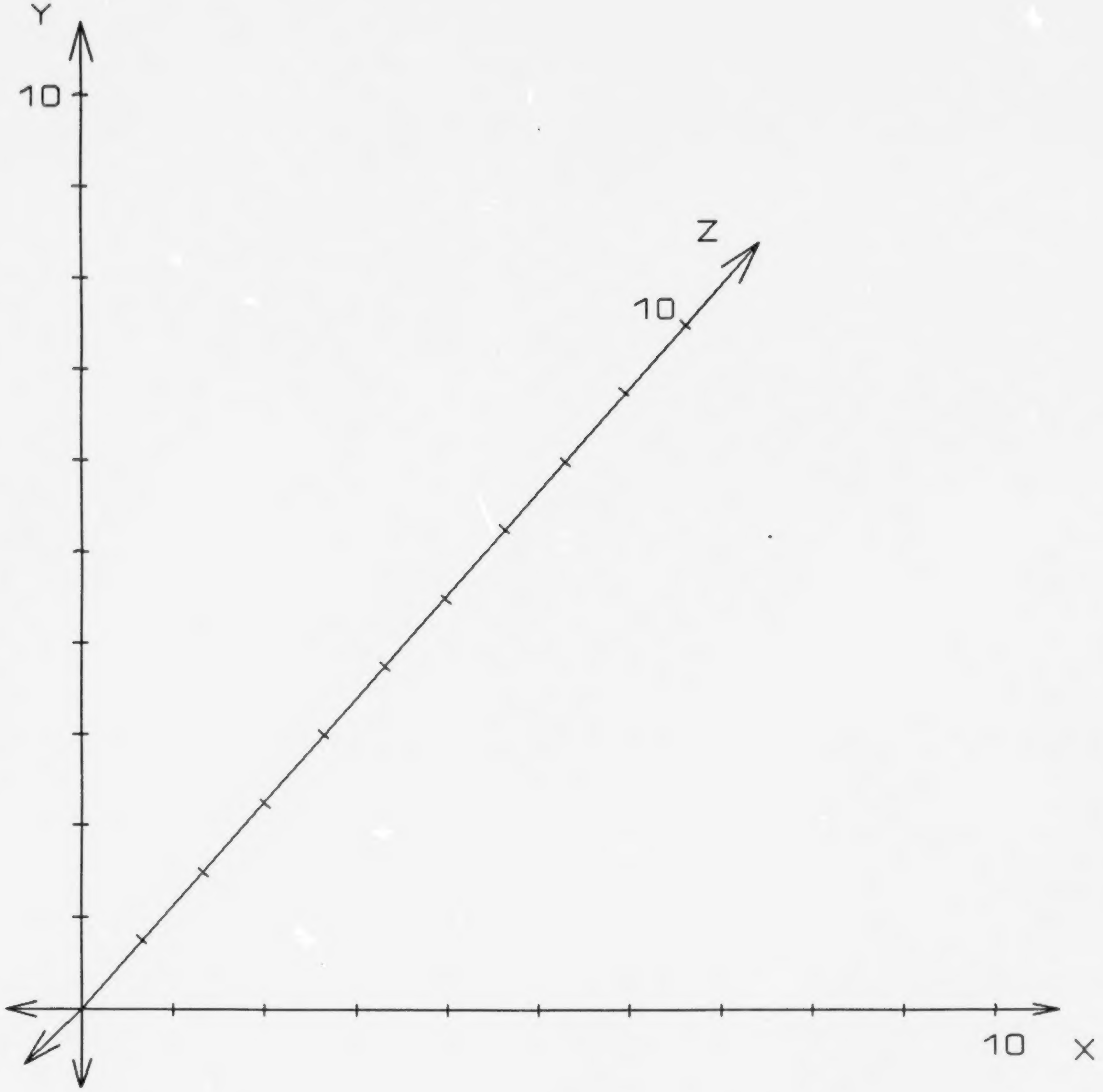

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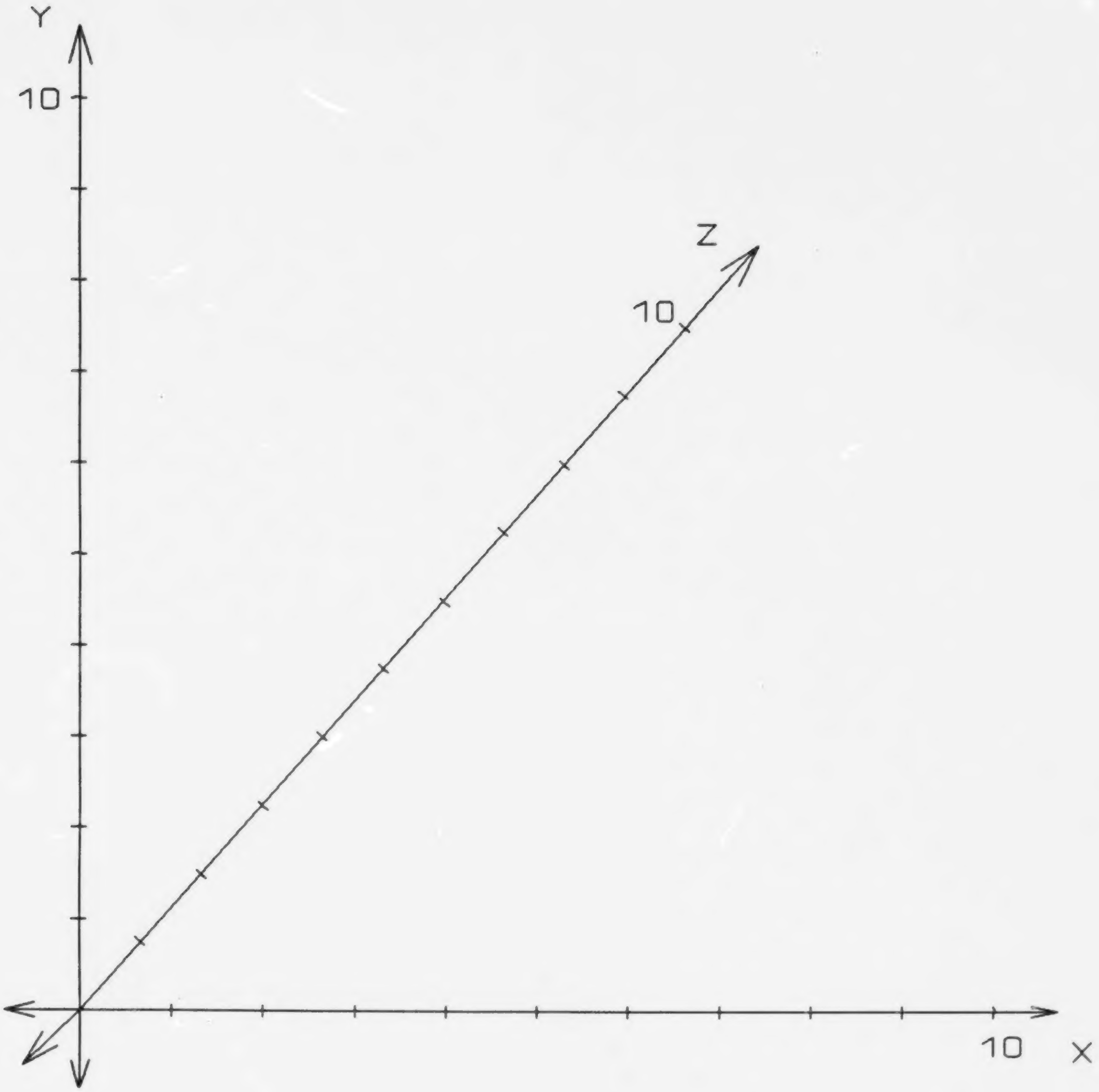


ACTIVITY 5: ADDITION OF VELOCITY VECTORS

TECHNOLOGICAL FRAMEWORK: You are going to take a trip to the moon from Cape Canaveral to the Sea of Tranquility. In what direction should you head your spaceship and why?

PURPOSE: To add velocities using the conveyor belt and moving track, and compare results to theoretical predictions, showing that velocities are actually vectors.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--Motion in one and two dimensions
  Frame of reference

Mathematics--Right triangle trigonometry
  Law of Sines and Cosines
  Vector Operations (Addition)

Technology skills--Assembly lines
  Space travel

PRE-REQUISITES:

Physics--Understanding of velocity motion detector and program

Mathematics--calculator skills
  slope
  definition of vector
  addition of vectors

Technology skills--Scorbot programming techniques

MATERIALS, EQUIPMENT, APPARATUS:	Scorbot slide and conveyor belt Motion detectors and accompanying software Two metal bars to connect conveyor belt to linear slide (see Figure S-5-1, "Slide and Conveyor") Small piece of angle iron to set motion detector on conveyor belt (see Figure S-5-1)
TIME FRAME:	Two 50-minute periods
TEACHING STRATEGIES:	Review of motion detector and program in Physics classroom Review of slopes and vectors in Physics classroom Technology laboratory Physics, Mathematics, Technology teachers involved
TEACHING METHODOLOGY:	Review addition and subtraction of vectors using velocity problems and accompany worksheets Review programming skills with the Scorbot and accompanying worksheets Teach operation of the motion detector and data analysis Laboratory demonstration Lab activity (four students to a lab group) Student laboratory write-up using computer printout and calculated slopes as data Post-lab analysis
FURTHER FIELDS OF INVESTIGATION:	Robotic programming Interpreting weather maps Astronomy

PROCEDURE:

One of the misconceptions of non-scientific people is that speed and velocity are the same thing, when in reality, speed is a scalar and velocity is a vector. The difference between these two concepts, scalar and vector, is crucial. A scalar, such as speed, is simply a number which represents how "fast" something is moving. For example, an automobile might move at a "speed" of 60 kilometers per hour; the number 60 in this example says nothing about the direction in which the car is traveling. The mathematical concept of vector is a more descriptive concept than scalar. A vector can be defined as anything having magnitude and direction. If we were to describe the movement of the automobile with a velocity, in other words a vector, the velocity would tell us the "speed," i.e., magnitude, and the auto's direction. The purpose of this lab activity is to show you, with the help of the motion detector and Scorbot accessories, that velocity is a vector, and velocities can be combined together. In step 3 of the lab, you will actually "see" how two velocities are combined into one, i.e., addition with the triangle rule, and how to calculate an object's direction, as well as its speed. When you complete this lab, you should be able to graphically add two vectors and understand the difference between speed and velocity.

1. Orientate the slide and conveyor belt so they move parallel to each other.

2. Secure the motion detector on the conveyor belt with a piece of angle iron and point the sensor directly at a stable object (a piece of wood, the wall, etc.).

3. Start with the motion detector at point A' of the slide and at point A of the conveyor (see Figure S-5-1, record this as position 1, using the Teach Menu of the Scorbot program).

4. Use the motion detector to record the distance-time graph of the conveyor belt and slide separately. First, manually run the belt from position A' to position B' recording the distance-time graph. Record this new position as position 2. (Make sure to print a separate graph for the movement of the slide and the movement of the belt.)

5. Calculate the slope (d/t = speed) for each distance-time graph.

6. Program the conveyor belt and slide so they move simultaneously in the same direction (simply go from position 1 to position 2) and record the object's distance-time graph using the motion detector software.

7. Calculate the slope.

8. Represent the first two velocities (conveyor belt and linear slide) as horizontal vectors (x-axis) on an x-y grid using different colored pens. The lengths of these vectors correspond to the speeds found in step 5.

9. Add the two vectors graphically and compare the result to the calculated slope from the distance-time graph recorded in step 7.

10. Program the conveyor belt and slide to move simultaneously in opposite directions and record the object's distance-time graph using the motion detector. (Go to position 1; move the belt to the opposite side manually from keyboard and record this as position 3; now move to position 2 and move the belt to the opposite side manually from the keyboard; record this as position 4; now moving from position 3 to position 4 will move the slide and belt simultaneously in opposite directions.)

11. Calculate the slope.

12. Represent the two velocities (conveyor belt and linear slide) as horizontal vectors (opposite directions on x-axis) and add graphically comparing result to calculated slope from distance-time graph recorded in step 11.

13. Turn the conveyor belt so it is perpendicular (90°) to the slide (using a protractor or by sight). (See Figure S-5-2, "Slide and Perpendicular Conveyor.")

14. Program the conveyor belt and slide to move simultaneously in the same direction (go from position 1 to position 2) and record the distance-time graph of the object using the motion detector software.

15. Calculate the slope.

16. Represent velocity of slide on x axis and velocity of conveyor on y axis (90°) and add graphically, comparing result to calculated slope from distance-time graph recorded in step 15.

17. Calculate the direction of the motion detector relative to your lab.

18. Now move the slide and belt in opposite directions at a 90° angle (go from position 3 to 4) and record the distance-time graph using the motion detector software.

19. Calculate the slope.

20. Represent velocity of conveyor belt on y axis (negative) and add graphically, comparing result to calculated slope from the distance-time graph recorded in step 19.

21. Calculate the direction of the motion detector relative to your lab.

ANTICIPATED PROBLEMS:

1. When adjusting the angle between the conveyor belt and slide, make sure that the apparatus is secured tightly.
2. When taking data while the slide and conveyor belt are at different angles, make sure the motion detector is pointed in the direction it will move (i.e., the teacher must anticipate the movement of the sensor prior to experiment).
3. Remember to print the distance-time graph after each trial (there should be six graphs total).
4. When calculating the direction of the motion detector in steps 17 and 21, there must be a frame of reference.

METHODS OF EVALUATION:

Teacher-generated quiz
Graphs and resulting calculations on lab report
Post-lab worksheet

FOLLOW-UP ACTIVITIES:

Teacher runs lab with conveyor belt turned 30° to slide and works through problem with class.

Textbook problems related to velocity.

REFERENCES, RESOURCES, VENDORS:

Robotics Training Program
Instructor's Manual
Copyright 1985 by Eshed Robotic Limited
Eshed Robotic, Inc.
45 Wall St.
Princeton, NJ 08540

IBM
International Business Machines Corp.
Department 984
P.O. Box 1900
Boulder, CO 80301-9191

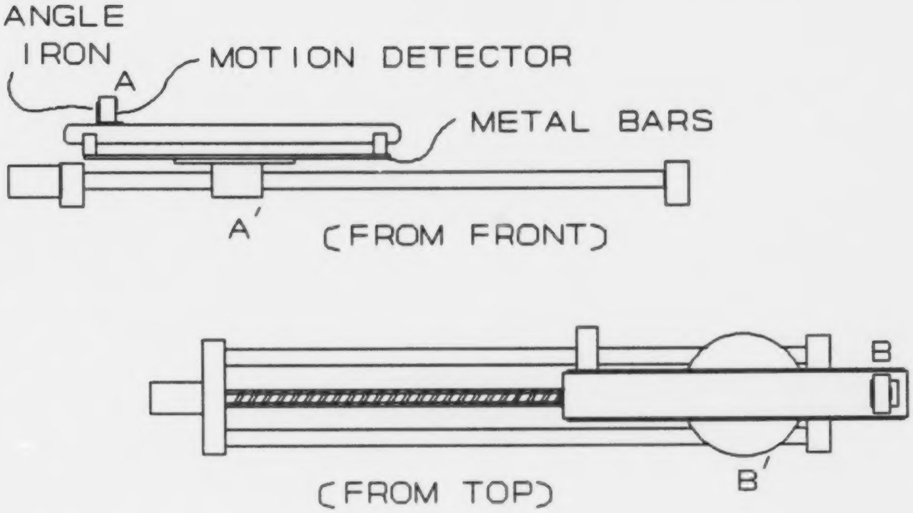

ANGLE
IRON
A
MOTION DETECTOR
METAL BARS
A'
(FROM FRONT)
B
B'
(FROM TOP)

Figure S-5-1

Slide and Conveyor

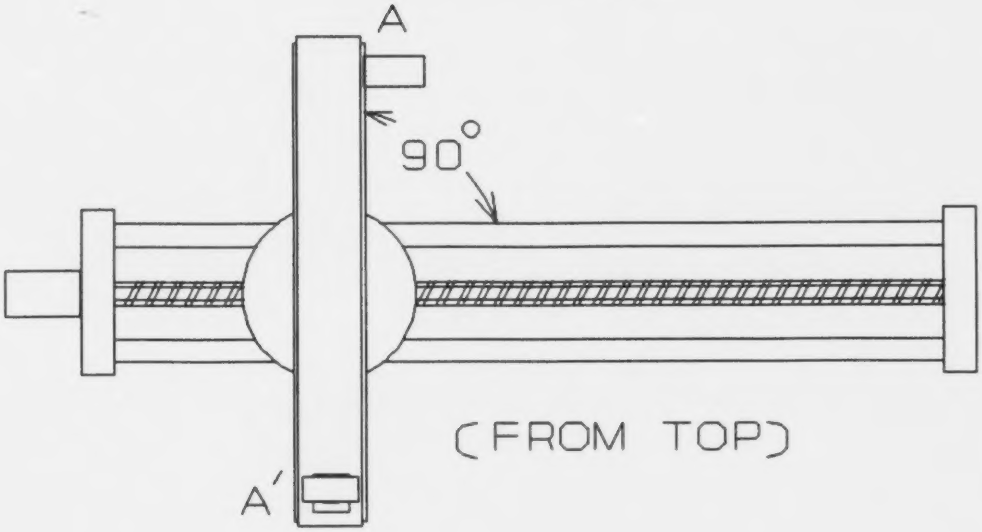

A
90°
(FROM TOP)
A'

Figure S-5-2

Slide and Perpendicular Conveyor

POST-LAB QUESTIONS: VELOCITY VECTORS

1. How does the slope of the distance-time graphs (excluding the first two distance-time graphs) compare to the length of the sum of the vectors in each part of the lab?

2. What does this say about the length of the vector sums?

3. What does the angle of the vector sums tell you about the simultaneous movement of the motion detector?

4. Explain what the vector sums on the graphs actually represent.

5. How does your explanation in #4 compare to the definition of a vector?

6. What is the difference between speed and velocity?

7. State some conclusions about velocities.

VELOCITY VECTORS MATHEMATICS WORKSHEET 1

CONCEPTS: Calculator skills
Slope

I. Use your calculator to change the following fractions into decimals (round to 4 decimal places if necessary).

1. 1/2 ____________________
2. 4/5 ____________________
3. 5/8 ____________________
4. 3/7 ____________________
5. 2/3 ____________________

II. Use your calculator to find the sine, cosine, and tangent of the following angle measures (make sure to have your calculator in the correct mode).

	Sine	Cosine	Tangent
1. 0°			
2. 30°			
3. 45°			
4. 60°			
5. 90°			
6. π/2 rads			
7. π/3 rads			
8. π/4 rads			
9. .524 rads			
10. 0 rads			

III. Find the slopes of the following line segments and represent them as a fraction and a decimal.

IV. How do the slopes of the above lines compare to the "steepness" of the lines?

VELOCITY VECTORS MATHEMATICS WORKSHEET 2

CONCEPTS:
Vector definition
Graphical definition of vectors
Pythagorean theorem

I. Define vector and show how it is represented graphically.

II. Draw $\vec{a} + \vec{b}$ for the following:

III. Find the missing length of each right triangle using the Pythagorean theorem and your calculator. Then calculate the slope of each hypotenuse.

VELOCITY VECTORS MATHEMATICS WORKSHEET 3

CONCEPTS:	Right triangle trigonometry Vector operations

I. Find the missing lengths and angles in the following right triangles by using the proper trigometric functions and your calculator.

II. Represent the sums of the following vectors graphically and then calculate their magnitude and direction.

III. Given the magnitude and direction of the following vectors, calculate the magnitude of the horizontal and vertical components.

IV. Represent the sums of the following vectors graphically and then calculate their magnitude and direction using the law of cosines and sines.

V. Solve the following problems:

1. Find the force required to pull a 50-pound weight up a ramp inclined at 20° to the horizontal.

2. A guy wire on a telephone wire makes an angle of 64° with the ground. One end of the wire is 12 meters above the ground. How long is the wire?

3. A plane with an air speed of 190 miles per hour is headed on a bearing of 30° south of east. A north wind is blowing (from north to south) at 15 miles per hour. Find the ground speed and the actual bearing of the plane.

4. The bearing from Winston-Salem, North Carolina to Danville, Virginia is 42° east of north. The bearing from Danville to Goldsboro, North Carolina is 48° east of south. A small plane piloted by Paul Maras, traveling at 60 kilometers per hour, takes 1 hour to go from Winston-Salem to Danville and 1.8 hours to go from Danville to Goldsboro. Find the distance from Winston-Salem to Goldsboro.

ACTIVITY 6: MEASURING BUOYANCY WITH A FORCE TRANSDUCER

TECHNOLOGICAL FRAMEWORK: An oil tanker is an extremely heavy ship (tons). How do you think it is possible for something this massive to float? When millions of barrels of oil are added to the tanker, what allows the ship to stay afloat?

PURPOSE: To measure the apparent loss in weight of an object when submerged in a fluid less dense than the object.

To measure the buoyant force exerted on gases less dense than air in a fixed volume (balloon), and measure the change in net upward force over an extended time period.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics - Archimedes principle
Diffusion
Static equilibrium
Electrical properties of wires

Mathematics - graphical analysis
Lineal equations

Technology - electrical hookup between computer and MPL box. Recording of data.

PRE-REQUISITES:	Physics--Static forces Density Mathematics--Computing volume Measuring techniques Technology skills--Working with valves and high pressure cylinders
MATERIALS, EQUIPMENT, APPARATUS:	Balloons and string Pasco force transducer Vernier MPLI computer interface and accompanying software Calipers to measure diameter of inflated balloons and metal spheres Helium, hydrogen, or any other gas less dense than air Electronic scale
TIME FRAME:	Three 50-minute class periods
TEACHING STRATEGIES:	Entire lab in Physics classroom
TEACHING METHODOLOGY:	Introduction to the Archimedes principle (The buoyant force on an object submerged in a fluid is equal to the weight of the fluid displaced) in class. Show how the Archimedes principle is derived from Newton's first law, the definition of pressure, and $P = hDg$. Demonstrate the operation of the force transducer. Briefly explain the operation of the force transducer mentioning the change of electrical resistance with the change in tension in the wire (qualitative). Introduce the equation of the volume of a sphere and equation relating upward net force with buoyant force, weight of the balloon, and weight of the gas in the balloon.

Use the accompanying mathematics worksheet to practice finding volumes and calculating buoyant force. Demonstrate measuring the volume of a sphere two ways. (Use a plastic caliper for diameter and a string for circumference.)

Review the calibration techniques using the Vernier software with the force transducer (see handout).

Demonstrate lab setup (see Figures S-6 [illegible] and S-6-2, "Downward Force" and "Upward Force," respectively. Note: Force transducer in Figure S-6-2 is upside down in order to arrive at positive values.

Lab activity in groups of four.

Use the follow-up questions as a class discussion and talk briefly about the diffusion of helium and hydrogen through the rubber balloon.

FURTHER FIELDS OF INVESTIGATION:

Weather balloons
Thanksgiving and Christmas parades
Promotional materials (blimps, etc.)

PROCEDURE:

A force transducer is a device that measures changes in force by using changes in electrical resistance. Forces on objects submerged in fluids will be measured with this device. There are two parts to this lab; in Part 1, you will use the force transducer to measure the force exerted on a metal sphere submerged in a liquid (water); and in Part 2, you will measure the force exerted on a helium-filled balloon in air. The change in upward forces as the gas diffuses from the balloon will also be measured over an extended period of time, and you will interpret, qualitatively, the rate of diffusion of different gases through a rubber membrane. The purpose of this lab is to study the effects of densities on the apparent weights of objects while submerged in a fluid.

Part 1

1. Calibrate the force transducer using the Vernier software.

2. Weigh the sphere in air with the force transducer and record __________.

3. Weigh the sphere while submerged in water (see Figure S-6-1) and record __________.

4. Calculate the buoyant force of the sphere with the above information and record __________.

5. Measure the diameter of the sphere with the caliper and record __________.

6. Calculate the radius of the sphere and record __________.

7. Measure the circumference of the sphere with a piece of string and record __________.

8. Calculate the volume of the sphere using either $V = 4/3\ (\pi r^2)$ or $V = c^3/6\pi^2$, and record __________.

9. Using the density of water, calculate the weight of water equal in volume to that of the sphere and record __________.

10. Calculate the buoyant force of the sphere using the Archimedes principle and record __________.

11. Compare the value in step 4 with the value in step 10.

Part 2

1. Calibrate the force transducer using Vernier software (after calibration, turn the force transducer upside down).

2. Weigh the empty balloon with an electronic balance and record ___________.

3. Fill the balloon with helium.

4. Measure the diameter of the filled balloon with the caliper while trying to form a sphere and record ___________.

5. Measure the circumference of the balloon with a string while trying to form a sphere and record ___________.

6. Calculate the volume using either $V = 4/3(\pi r^2)$ or $V = c^3/6\pi^2$.

7. Look up the density of air in the textbook and record ___________.

8. Calculate the buoyant force on the balloon with the above information and the formula $W = VDg$ and record ___________.

9. Connect the balloon to the force transducer with string as in Figure S-6-2.

10. Record the net upward force of the balloon with Vernier software.

11. Look up the density of helium in the textbook and record ___________.

12. Calculate the weight of helium in the balloon using the same formula used in step 8 and record ___________.

13. Calculate the initial bucyant force from net upward force recorded with Vernier software and using the formula given in class $F_B = F_{Net}$ - (Weight of balloon + Weight of helium in the balloon) and compare with theoretical calculations.

14. Repeat steps 1-13 with a hydrogen-filled balloon of equal volume, leaving the helium-filled balloon in place.

15. Leave lab set up over night with software set up to take data all night.

16. Print the graphs of the net upward force from the computer after the 24-hour period.

17. Analyze the graph for use in follow-up question worksheet.

ANTICIPATED PROBLEMS:	Mathematical calculations Calibration of force transducer Filling the balloons with an equal volume of gas
METHODS OF EVALUATION:	Teacher-generated quiz Lab report and worksheet
FOLLOW-UP ACTIVITIES:	Use force transducer to calculate the rate of diffusion of helium through the balloon
REFERENCES, RESOURCES, VENDORS:	Vernier Software 2920 S.W. 89th St. Portland, OR 97225 Pasco Scientific 10101 Foothills Blvd. P.O. Box 619011 Roseville, CA 95661

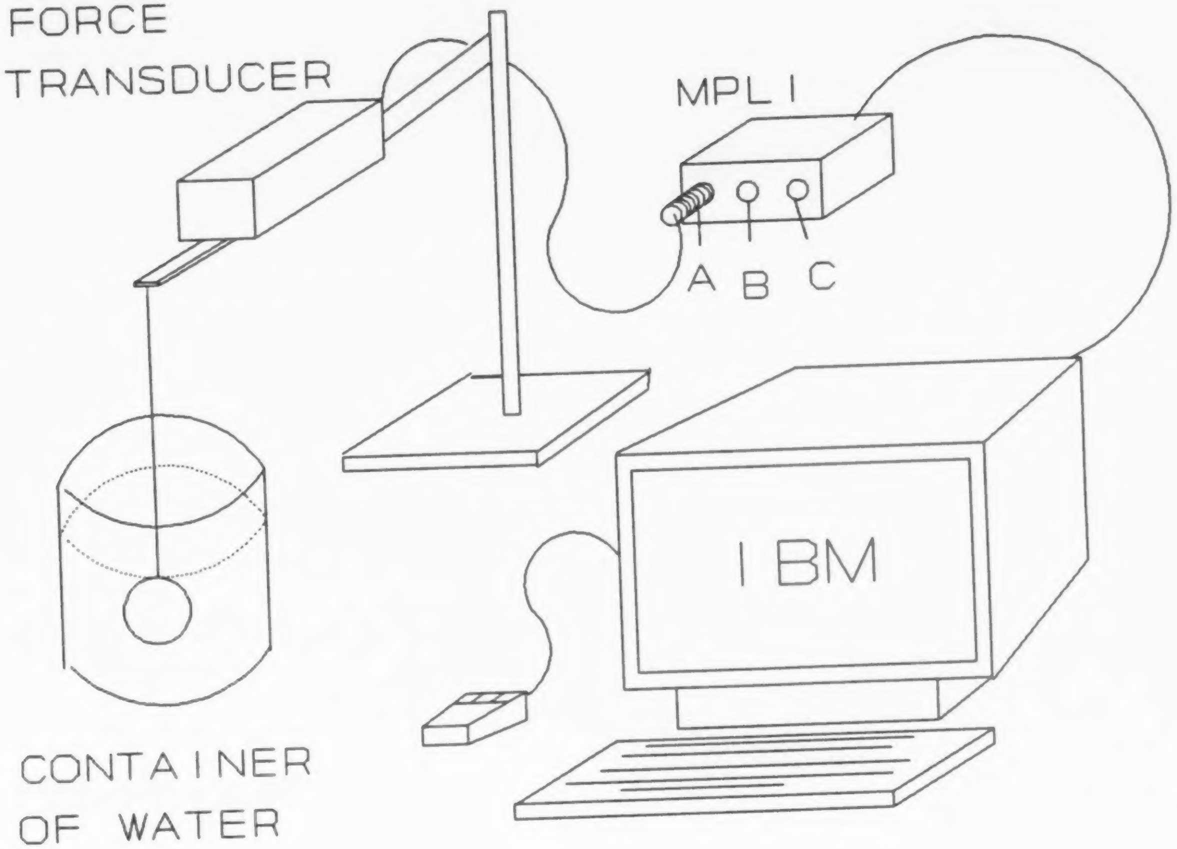

FORCE
TRANSDUCER
MPL I
A
B
C
IBM
CONTAINER
OF WATER

Figure S-6-1

Downward Force

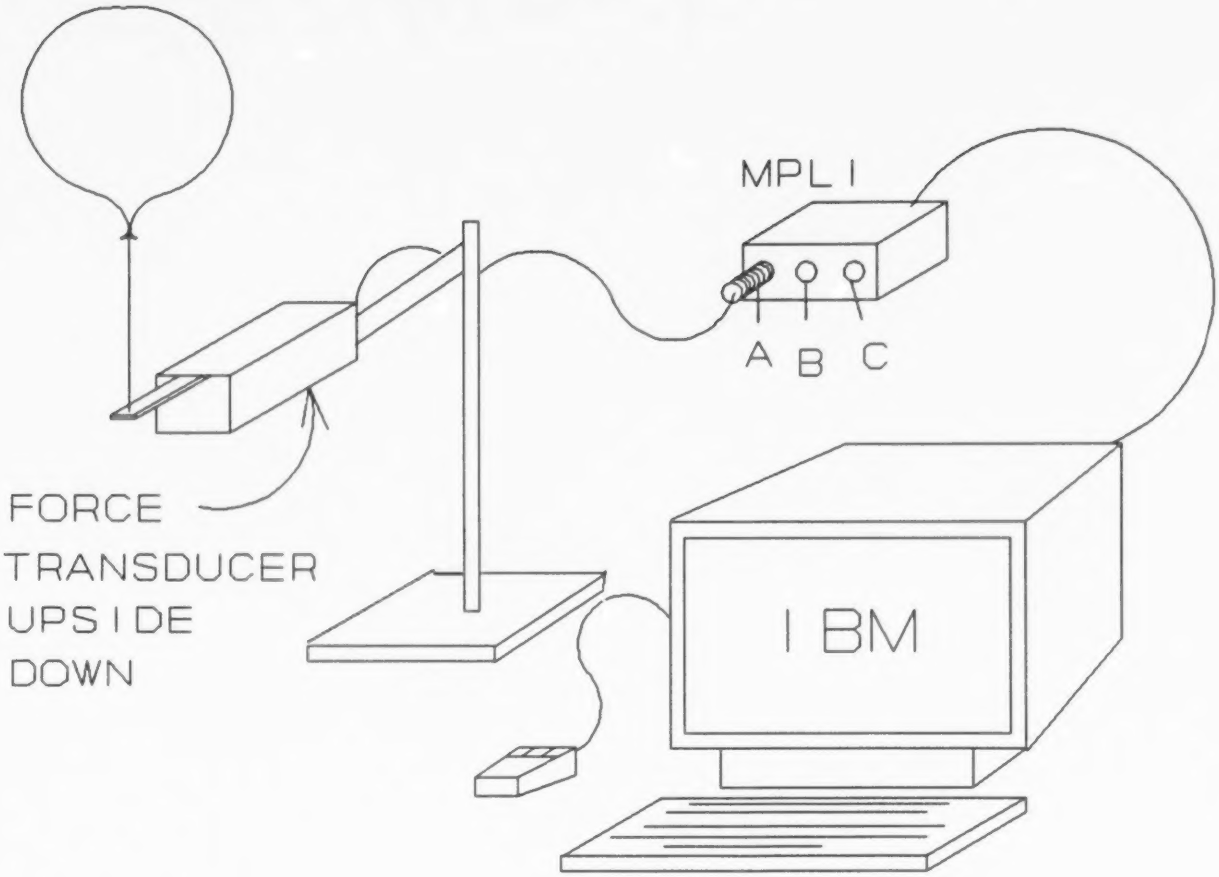

MPLI
A
B
C
FORCE TRANSDUCER UPSIDE DOWN
IBM

Figure S-6-2

Upward Force

FORCE TRANSDUCER POST-LAB QUESTIONS

1. What changes inside the force transducer when different weights are applied to it?

2. Why didn't the metal sphere float in the water?

3. Why is the weight of the metal sphere different in air than it is in water?

4. What would you expect to happen to the apparent weight of the metal sphere if the water was replaced with a more dense liquid?

5. Which balloon (helium- or hydrogen-filled) produced the greatest initial net upward force?

6. What does your answer from number 1 tell you about the density of helium? of hydrogen?

7. Was there any difference in the initial buoyant forces?

8. What does your answer from number 3 tell you about buoyant forces? What do they depend on?

9. Which balloon had the highest final net upward force? highest buoyant force?

10. What does your answer from number 5 tell you about helium? about hydrogen?

11. At any moment, how does the pressure inside the balloon compare to the air pressure outside the balloon?

12. If the air pressure outside the balloon is 0 (vacuum), what would you expect to happen?

Calibration of the Force Transducer Using the Vernier Software

1. Choose "calibration" from the main menu and "calibration" from the select menu.

2. Type "force" when asked for a label and "newtons" when asked for a unit.

3. Choose the appropriate input (A, B, or C).

4. When asked for input 1, have the force transducer unloaded and enter 0 when the voltage stabilizes.

5. When asked for input 2, load the force transducer with a known weight and enter that weight when the voltage stabilizes.

6. When asked to save the calibration, choose "yes" and type your name for the file.

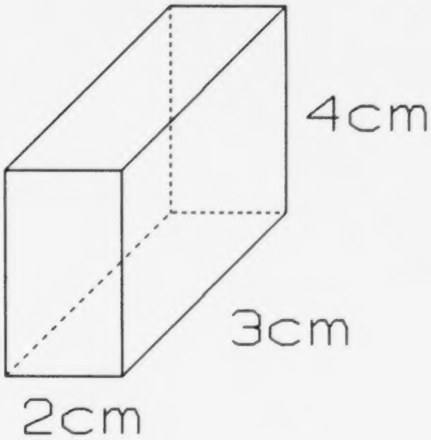
FORCE TRANSDUCER MATHEMATICS WORKSHEET

Volumes and Buoyant Forces

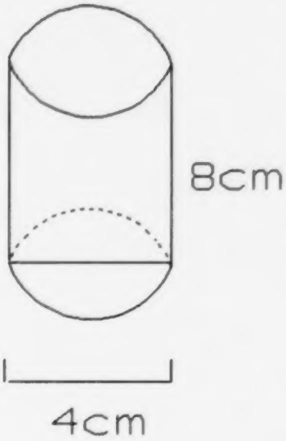
Buoyant Forces with the Force Transducer

Calculate the volume of the following figures:

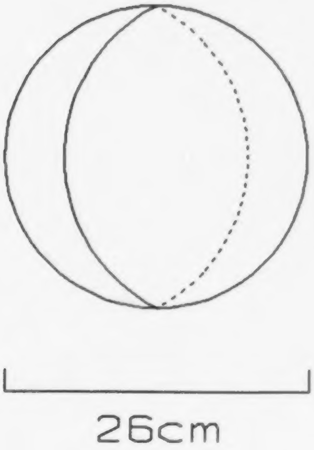
1.



2.



3.



Lamb/Maras/Salabura
Shepard High School
Activity 6
Measuring Buoyancy with a
Force Transducer

Using the Archimedes principle, calculate the buoyant force exerted on the following objects:

4. A 4 cm by 5 cm by 6 cm rectangular prism of gold submerged in water.

5. A cylindrical piece of silver submerged in 10-weight motor oil which measures 40 cm high and has a diameter of 15 cm.

6. A helium-filled spherical balloon (25 cm in diameter) "submerged in air."

ACTIVITY 7: TORQUE WRENCH LAB

TECHNOLOGICAL FRAMEWORK:

Driving to school this morning, your tire went flat. While changing your tire, you found it impossible to remove two of the lug nuts holding the wheel on to the hub. What can you do to remove these? After changing your tire, you figured it was too tight before; so, you do not tighten the lug nuts completely. What can happen?

PURPOSE:

1. Measure the torque on a bolt by using an industrial torque wrench.
2. Use an impact wrench to tighten bolts.
3. Calibrate an impact wrench by using a torque wrench.
4. Calculate force by using a measured torque and a measured lever arm.
5. Convert ft-lbs. to in-lbs.
6. Compare the factory rating of a bolt to its measured shear strength.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:	Physics--torque and rotational equilibrium stress, strain, and shear modulus Mathematics--vector cross products Technology skill--how to use a torque and impact wrench; how to read bolt ratings for shear strength
PRE-REQUISITES:	Physics--linear measurement, force, displacement, tensile strength Mathematics--linear equations, unit conversions, direct proportions
MATERIALS, EQUIPMENT, APPARATUS:	One 12" steel angle with 5, 3/8-24 NF holes equally spaced One 12" steel angle with 3, 1/4-20 NC holes equally spaced 3/8-24 NF bolts and nuts 1/4-20 NC grade 2 bolts 1/4-20 NC grade 5 bolts 1/4-20 NC grade 8 bolts 1/4-20 NC hex nuts One impact wrench and air supply Two torque wrenches metered in ft-lbs. (250 ft-lbs. max.) 3/8" drive, 7/16 and 9/16 sockets
TIME FRAME:	Physics--one 50-minute class period Mathematics--1/2 50-minute class period Technology activity--one 50-minute class period
TEACHING STRATEGIES:	Technology--Metals laboratory Physics, Mathematics, and Technology teachers

TEACHING METHODOLOGY:

Introduce torque and review proportions, linear equations, and factor label in pre-lab session.

Introduce relationship between tensile and shear strength.

Demonstrate how to make a torque wrench.

Demonstrate laboratory activity

Student lab writeup

Introduce non-right angles and their effect on torque in post-lab sessions using the accompanying worksheet.

FURTHER FIELDS OF INVESTIGATION:

Automotive, Construction, Military, Aerospace, and Marine industries.

PROCEDURE:

A torque is that which produces or tends to produce rotation and is measured in foot-pounds, inch-pounds, or Newton-meters (T = Fd). One of the easiest ways to measure it is with a torque wrench. A torque wrench is a tool used in industry that allows a person to apply a certain torque to a nut while reading that value on the wrench. One example of where this is necessary is in the construction of automobile engines. When a gasket is used to seal the gap between two metal parts, as in the engine block, the nuts and bolts must be evenly tightened so the gasket will not warp, which would break the seal. A torque wrench is used to be sure pressure is evenly distributed on a surface when tightened. There are countless ways torque wrenches are used in industry, and the purpose of this lab activity is to not only teach you the concept of torque, but to show how it is applied in the real world through the use of a torque wrench.

Part 1

1. Take angle iron #1 and securely clamp in a vice.
2. Using the air impact wrench, tighten down a nut on first bolt to setting #1. Repeat tightening for settings 2-5 on the remaining four bolts.
3. Take the ft-lb torque wrench and check each bolt and record each value.
4. Convert the torque in ft-lbs. to in-lbs. and record each value in Figure S-7-1 ("Torque Lab Data Sheet--Impact Wrench").
5. Measure the length of the wrench (lever arm) in inches and calculate the force applied to the wrench and record each value in Figure S-7-1.

Part 2

1. Take plate #3 with three different grade bolts and tighten a hex nut on each bolt with the torque wrench until the bolt shears off or you cannot turn it anymore. When the bolt shears, record the torque in Figure S-7-2 ("Torque Lab Data Sheet--Torque Wrench").

2. Convert torque value into in-lbs.

3. Measure the length of the wrench (lever arm) in inches and calculate the force applied to the wrench. Record each value in Figure S-7-2.

4. Compare the shear rating of the bolt to the torque needed to actually shear the bolt and record that value in Figure S-7-2.

5. Check measured data with shear rating of bolt and calculate the difference.

ANTICIPATED PROBLEMS:

Angle must be securely fastened. Threads might strip out of the angle; try running a hex nut down on the angle before you start the lab. (Double nut)

METHODS OF EVALUATION:

Practical Quiz--Have each student measure the torque needed to shear a bolt and compare that value to the factory bolt rating.

Have students tighten a bolt to a specified torque.

Check calculated forces in data table.

FOLLOW-UP ACTIVITIES:

To explain how torque is proportional to the length of the level arm as well as the force applied by adding pipe to the wrench and breaking the seemingly unbreakable bolt.

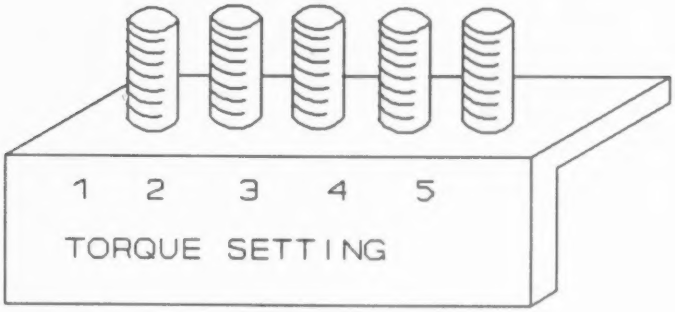
Find and record 10 items at home that depend on torque.

REFERENCES, RESOURCES, VENDORS

Mechanics handbook publisher:
Industrial Press Inc.
200 Madison Ave.
New York, NY 10016

Paxton/Patterson
5719 W. 65th St.
Chicago, IL 60638
(800) 323-8484

Example 1:



NOTE: 1/4" STEEL ANGLE - ALL BOLTS OF SAME GRADE

Figure S-7-1

Torque Lab Data Sheet--Impact Wrench

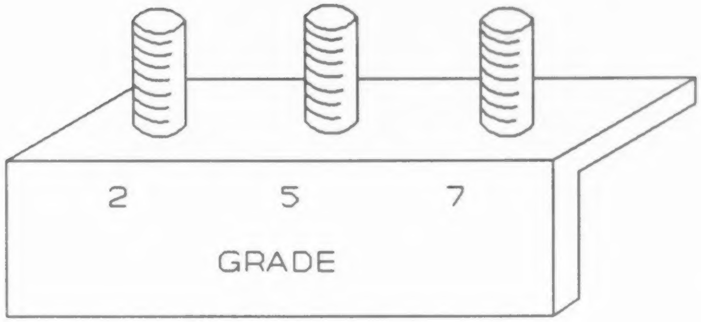
Torque Lab Data Sheet--Impact Wrench

Impact Wrench Torque Setting - Data					
Bolt	Wrench Setting	Torque ft-lbs	Torque in-lbs	Length of Lever Arm	Force Needed to Start the Nut Moving
1					
2					
3					
4					
5					

$$\frac{\text{ft. lbs}}{1} \times \frac{\text{12 in.}}{\text{ft.}} = \text{in lbs}$$

$$\text{Force lbs.} = \frac{\text{Torque in. lbs}}{\text{Length in.}}$$

Example 2:



NOTE: 1/4" STEEL ANGLE

Figure S-7-2

Torque Lab Data Sheet--Torque Wrench

Torque Wrench--Shear Strength of Bolts					
Bolt	Grade	Torque ft-lbs	Torque in-lbs	Length of Lever Arm	Force Needed to Shear the Bolt
1					
2					
3					

$$\frac{\text{ft. lbs}}{1} \times \frac{\text{12 in.}}{\text{ft.}} = \text{in lbs}$$

$$\text{Force lbs.} = \frac{\text{Torque in. lbs}}{\text{Length in.}}$$

Suggestions: Thread a nut down to the angle before you start the lab activity. This will prevent the threads from stripping.

TORQUE WRENCH POST-LAB QUESTIONS

1. If you need to change a flat on your car and the bolts are too tight to remove, what can you do to increase the amount of torque being applied to the bolt?

2. Why is it easier to turn a screw when the handle of the screw driver is larger?

3. Is it easier to turn a screw when the screw driver is longer?

4. Give two examples of when a bolt has to be tightened to a specific torque.

5. If the tensile strength of a grade 2 bolt is 80,000 psi, what is the shear strength of a 1/4-20 bolt if shear strength is 60% of tensile strength?

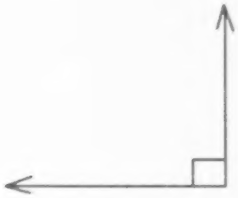
6. Repeat question #5 for a grade 5 bolt (tensile strength = 120,000 psi) and a grade 8 bolt (tensile strength = 150,000 psi) of the same diameter.

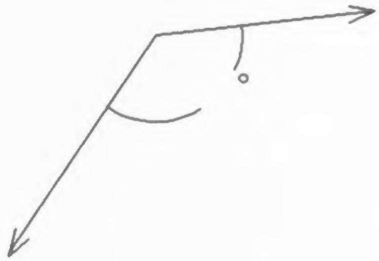
PHYS-MA-TECH

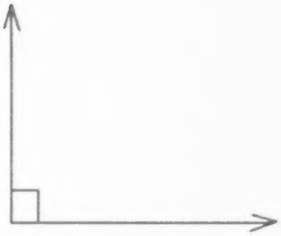
AN INTEGRATED PARTNERSHIP

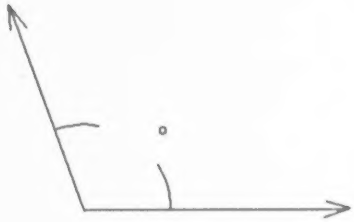
TORQUE WRENCH MATHEMATICS WORKSHEET

I. Calculate the magnitude of the torque resulting from the vector cross product F x S.









II. Use the right hand rule to determine the direction of the resulting vector T in the above problems (either out of the paper's plane or into it!).

1. __________

2. __________

3. __________

4. __________

ACTIVITY 8: COMPUTER INTERFACED THERMOCOUPLE

TECHNOLOGICAL FRAMEWORK: It's a cold winter day and your gas furnace does not work. What would you look for in finding the cause of the problem?

PURPOSE: To study the workings of a thermocouple, its applications to industry, and to use it to measure high and low temperatures.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--EMF (voltage) caused by a temperature difference between the ends of a thermocouple

Mathematics--interpreting graphs of functions

Technology skills--melting temperatures of different materials

PRE-REQUISITES:
EMF
Potential difference
Current
Definition of temperature
Use of the Vernier thermocouple and related software

MATERIALS:

- Thermocouple
- Computer interface and appropriate software
- Bunson burner
- Hot plate
- Propane torch
- Soldering iron
- Solid carbon dioxide (dry ice)
- Liquid nitrogen

TIME FRAME: One 50-minute period

TEACHING STRATEGIES:

Physics teacher in classroom

Mathematics teacher in computer lab

Technology teacher to run lab in Physics classroom

TEACHING METHODOLOGY:

Review the meaning of temperature and properties of matter that are functions of temperature, for example, color, liquid volume, electrical resistance, expansion of solids, pressure of a confined gas, etc.

Review the fact that temperature does not vary when matter is experiencing a phase change (graph will flatten at this point).

Mathematics teacher reviews linear equations and interpreting graphs of functions (accompanying worksheet) and introduces software in computer lab.

Introduce the concept of causing an EMF from a temperature difference using a thermocouple, emphasizing the linearity of the function.

Technology teacher discusses the construction, application, and use of a thermocouple in Physics classroom.

Construct a simple thermocouple and demonstrate its use with a voltmeter.

Lab activity in Physics lab with all three teachers.

FURTHER FIELDS OF INVESTIGATION: Measuring temperature in difficult-to-access places (inside a silo, in a molten metal, inside a flame)

PROCEDURE: When two different conducting wires are connected at their ends and a temperature difference is maintained between them, an EMF (voltage) is produced. The EMF is proportional to the temperature difference. A thermocouple can be calibrated by placing one end (junction) in ice water and the other junction separately in two materials (e.g., water) of known temperature. Once calibrated, the thermocouple can be used to measure unknown temperatures. It has an advantage over other more familiar thermometers (i.e., that it has a far greater range). In this experiment, you will use a thermocouple to measure very high and very low temperatures.

1. Connect the circuit using Figure S-8-1, "Thermocouple Hookup."

2. Calibrate the thermocouple using known temperatures (ice water, boiling water, molten lead) by:

    a. placing both junctions in an ice water bath.

    b. from the main menu, choose Calibration.

    c. from the calibration menu, choose Calibrate Input.

    d. Now choose the appropriate input jack.

    e. Choose Yes when warning appears.

    f. Now the program will ask for an input label and units; type "temp" and C, respectively.

    g. When input potential stabilizes (to a hundredth of a volt), press Enter.

    h. Input 0° when prompted for temperature #1.

    i. Take red junction of the thermocouple and put it into a cup of water of known temperature (boiling).

    j. When the next input potential stabilizes, press Enter and input 100° when prompted for temperature #2.

   k. Next, the program will ask if you want to save the calibration to a file; choose Yes and title the file with your name.

   l. Finally, exit to the main menu and choose Monitor Input.

3. From the main menu, choose Real Time Graph and turn on the appropriate options.

4. Enter -200° as a minimum input and 1000° as a maximum input.

5. Choose Yes when prompted to store the data.

6. Carefully put red junction into the sample (e.g., Bunson burner), while leaving the black junction in the ice bath. Make sure both junctions are immobilized.

7. Choose an appropriate time for duration and leave the other options at their default settings. When you press the final Enter, your experiment will begin.

8. When the experiment is complete (stabilized temperature), print the graph.

9. Repeat steps 3-8 for other samples.

10. Determine the following:

    a. The melting point of 60-40 solder.

    b. The melting point of 40-80 solder.

    c. The temperature at the bottom, middle, tip, and 5 cm above a Bunson burner flame.

    d. The temperature at the bottom, middle, tip, and 5 cm above a propane torch flame.

    e. The temperature of dry ice.

    f. The temperature of liquid nitrogen.

ANTICIPATED PROBLEMS:	Circuit hookup Calibration mistakes and an inconsistent graph with expected values Dangerous temperatures (follow strict safety procedures)
METHODS OF EVALUATION:	Grade lab on the basis of determining the correct material, correct melting point, correct temperature, etc. Teacher-generated quiz Follow-up questions and printed graphs
FOLLOW-UP ACTIVITIES:	Examine temperature-sensitive safety devices using thermocouples (e.g., natural gas stoves, natural gas hot water heaters, other temperature difference devices).
REFERENCES, RESOURCES, VENDORS:	Vernier Software 2920 S.W. 89th St. Portland, OR 97225

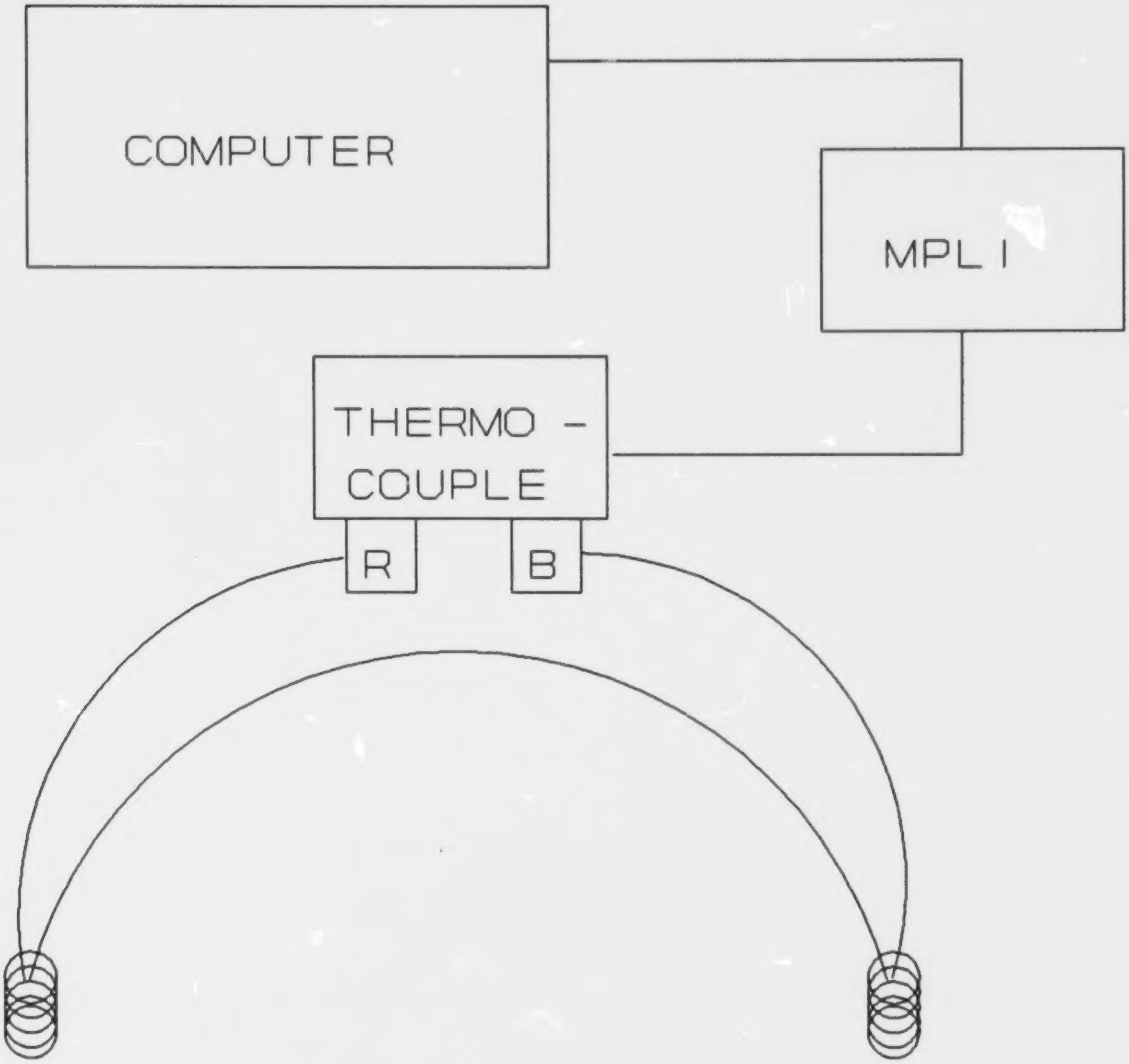

COMPUTER
MPL I
THERMO - COUPLE
R
B

Figure S-8-1

Thermocouple Hookup

POST-LAB QUESTIONS

1. What does temperature measure?

2. What is the relationship between the temperature differences of the junctions and the EMF (voltage) generated?

3. What does the flat part of the temperature curve for solder represent?

4. What is the difference between 60-40 solder and 40-60 solder, and at what temperatures do they melt?

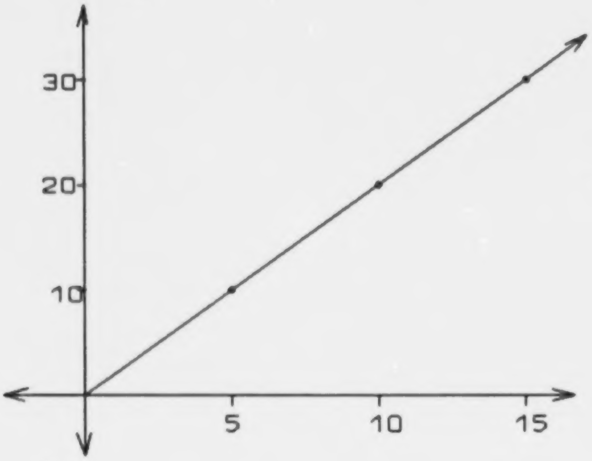
5. Explain why the different solders have different melting temperatures.

6. What is the hottest part of the flames from the Bunson burner and the propane torch? the coolest part of the flames?

7. Explain why a thermocouple would be used, as opposed to a mercury thermometer, and give three specific examples of where a thermocouple might be used in industry.

COMPUTER INTERFACED THERMOCOUPLE MATHEMATICS WORKSHEET

I. Suppose that the measure (in cm) of the radius of a tree trunk varies directly with the tree's age. The function a(r), which gives the age of the tree from its present radius, is given below.



1. How old is the tree when its radius measures 10 cm?

2. How many cm does the tree's radius grow per year?

3. Mathematically, your answer from #2 is called the ________________ of the line.

4. Write an equation which represents the age of the tree given the length of its radius.

5. Find a(r).

6. How old is the tree when the radius of the tree measures as follows?

   (a) 7.85 cm

   (b) 18 cm

   (c) 3 m

II. Graph the lines F(C) = (9/5) (C + 32), and

C(F) = (5/9) (F - 32)

and determine the point (temperature) at which degrees F have the same numeric value as degrees C.

LIST OF ACTIVITIES

AURORA WEST HIGH SCHOOL

		Inclusive Page Nos.
Activity 1	Fiber Optics Multiplexing System . . .	468-490
Activity 2	Jack of All Trades	491-523
Activity 3	Inertia Welder (Friction Welding) . .	524-534
Activity 4	Electromagnetic Door Control	535-553
Activity 5	Smoke Alarm	554-566
Activity 6	Programmable Home Thermostat	567-577

ACTIVITY 1: FIBER OPTICS MULTIPLEXING SYSTEMS

TECHNOLOGICAL FRAMEWORK: Multiplexing is used by the telecommunications industry to send multiple communications over a single optical fiber.

PURPOSE: To investigate different methods of multiplexing in fiber optic cable.

To investigate reflection and refraction of light and the application of these concepts to fiber optic transmission.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--waves, optics, and sound.

Mathematics--geometry, trigonometry, direct and inverse proportions.

Technology--telecommunications.

PRE-REQUISITES: Geometric constructions; basic CAD skills.

Geometric constructions generated with CAD, waves, optics, and trigonometry.

MATERIALS, EQUIPMENT, APPARATUS: CAD software (AutoSketch), as listed with activities.

TIME FRAME:	4-20 class periods, depending on the extent of the follow-up activities used.
TEACHING STRATEGIES:	Activity may take place in Physics or Technology lab. Area must be darkened. Working in groups of eight students will do activities rotating from one station to the next. Technology teacher will build cradles to support the lucite rods having means to align the laser at different angles to the lucite rod end.
TEACHING METHODOLOGY:	Lecture and discussion on reflection, refraction, and light velocity in different media. Lecture and discussion on different aspects of telephone communications including optical fiber communication. Students will complete the lab activities in this unit in larger groups (e.g., eight). Visit Scitech Science and Technology Interactive Center; visits to operation centers, repair facilities, production sites, communication museums, etc.; extra credit projects (construct communication system).
FURTHER FIELDS OF INVESTIGATION:	Telephone communication systems, computer networks, electronic mail.

PROCEDURE: Activity 1 - Observations with a clear lucite rod

Materials: 1-1/2" diameter x 2' to 3' long clear lucite rod. Ends must be polished until transparent and scratch-free.

Procedure: Step 1: Look into the end of the lucite rod.

Step 2: Note what you see through the end on the lab sheet.

Step 3: Look at the lateral surface of the rod through one end.

Step 4: Note what you see through the lateral surface on the lab sheet.

Step 5: Complete the lab sheet for Activity 1.

Activity 2 - Critical Angle

Materials:
Semi-circular clear plastic pie dish
Laser
Polar graph paper

Procedure: Step 1: Fill semi-circular dish about half full of water.

Step 2: Set the semi-circular dish on the polar graph paper as shown in Figure A-1-1, "Refraction - Critical Angle."

Step 3: Shine laser beam into the water as shown in Figure A-1-1, with the beam just below the surface of the water.

Step 4: With the laser beam always directed to the center of the semi-circular dish, slowly rotate polar graph paper and dish together.

Step 5: As the dish is rotated, note on the lab sheet what happens to the intensity of the reflected and refracted rays.

Step 6: Note on the lab sheet the angle of the incident laser beam when the angle of refraction becomes 90°.

Step 7: Continue to rotate the polar graph paper and dish together until the angle of the incident laser beam is about 85° and note on the lab sheet what happens.

Step 8: Complete the lab sheet for Activity 2.

Activity 3 - Digital transmission over optical cable

Materials: One length of optical cable (approximately 18"), one end of which has a connector; one 2' length of 2" diameter PVC pipe and one end cap for same; one video camera; one color video monitor; high intensity light source such as a film strip projector; at least two transmission color filters (such as red and green); one student finger (DIGITizer).

Procedure: Step 1: Drill correct size hole in center of PCV end cap to accommodate fiber optic connector.

Step 2: Insert fiber optic connector into the end cap pre-drilled hole.

Step 3: Attach end cap to the 2' length of PVC pipe.

Step 4: One student will hold the open end of the pipe to the video camera lens; another student will hold the open end of the fiber optic cable in front of the light source and DIGITize signal (see Figure A-1-2, "Digital Fiber Optics").

Step 5: Note on lab sheet what is observed on the T.V. monitor.

Step 6: Repeat Steps 4 and 5 with colored transmission filters in front of the light source.

Activity 4 - Multiplexing by Frequency

Materials: 2' to 3' clear lucite rod 1-1/2" diameter, one 12" long 1/2" diameter transparent red lucite rod curved to 150° angle (heat lucite with heat gun or in a plastics oven and form curve), one 12" long 1/2" diameter transparent green lucite rod similarly curved, two light sources such as film strip projectors, appropriate sized PCV caps to fabricate connectors between 1/2" rods and light source and between 1/2" rods and 1-1/2" rod (see Figure A-1-3, "Multiplexing Construction"), one prism, two white screens, two ring stands and two vinylized Buret clamps, and one PCV cap 1-1/2" inside diameter with narrow slit cut across end (hack saw kerf will be good).

Procedure: Step 1: Set up as in Figure A-1-4, "Multiplexing by Frequency."

Step 2: Turn on light sources.

Step 3: Describe, on lab sheet, the appearance of the end of the 1-1/2" diameter lucite rod.

Step 4: Describe what you see on the screen directly in front of the large rod.

Step 5: Place narrow slip cap on open end of the 1-1/2" lucite rod with slit vertical.

Step 6: Place the prism approximately 2" in front of the light beam in such a way as to separate the spectrum.

Step 7: Describe, on lab sheet, what you see on screen 2.

Step 8: Complete the lab sheet for Activity 4.

Activity 5 - Multiplexing by incident angle

Materials: Two lasers, one 2' length of 1-1/2" diameter clear lucite rod with ends polished, one white screen, two ring stands, and two vinylized Buret clamps.

Procedure:

Step 1: Set up as indicated in Figure A-1-5, "Multiplexing by Path Length."

Step 2: Align one laser such that the beam reflects only once off the lateral surface of the rod.

Step 3: Align the second laser such that the beam reflects twice off the lateral surface of the rod.

Step 4: Describe, on the lab sheet, what you see on the screen.

Step 5: Turn off the second laser.

Step 6: Align the first laser such that you have as many internal reflections as possible.

Step 7: Describe, on the lab sheet, what you see on the screen.

Step 8: Remove the screen.

Step 9: Describe, on the lab sheet, what you see on the end of the rod.

Step 10: Complete the lab sheet for Activity 5.

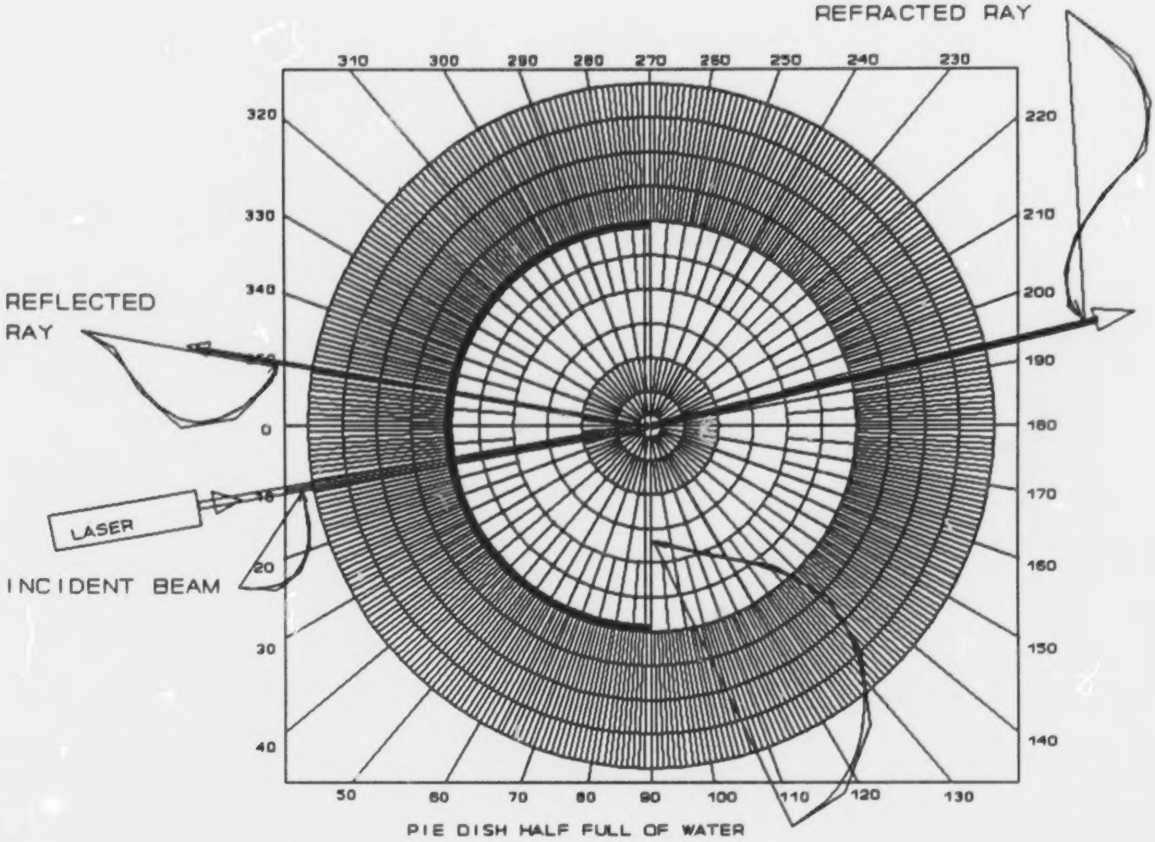

REFRACTED RAY
310
300
290
280
270
260
250
240
230
320
330
340
350
0
15
20
30
40
220
210
200
190
180
170
160
150
140
REFLECTED RAY
LASER
INCIDENT BEAM
50
60
70
80
90
100
110
120
130
PIE DISH HALF FULL OF WATER

Figure A-1-1

Refraction - Critical Angle

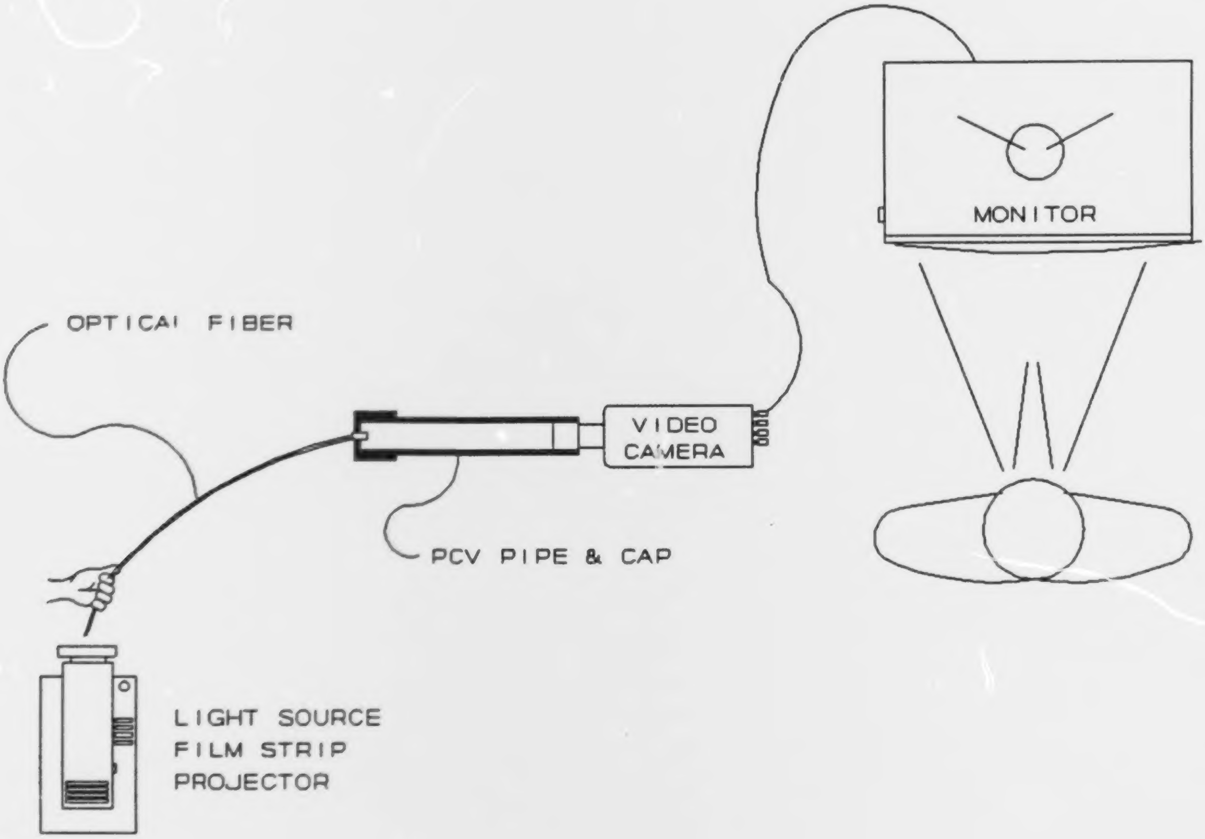
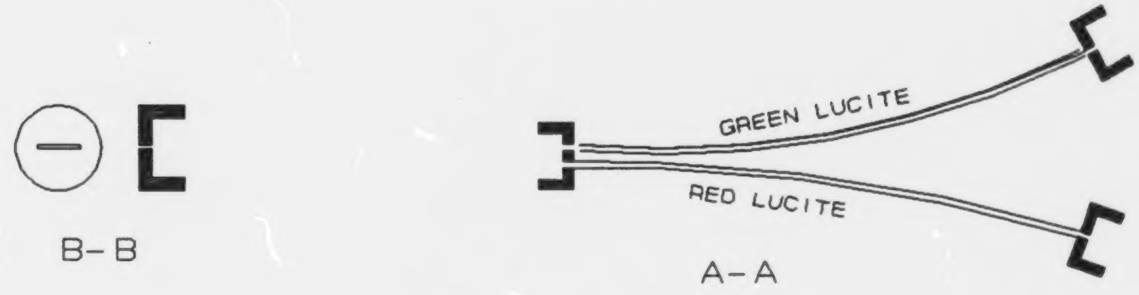

OPTICAL FIBER
VIDEO CAMERA
MONITOR
PCV PIPE & CAP
LIGHT SOURCE
FILM STRIP
PROJECTOR

Figure A-1-2

Digital Fiber Optics


B-B
GREEN LUCITE
RED LUCITE
A-A

ALL 4 CAPS MADE FROM
ALUMINUM MACHINED IN METAL
WORKING LAB.

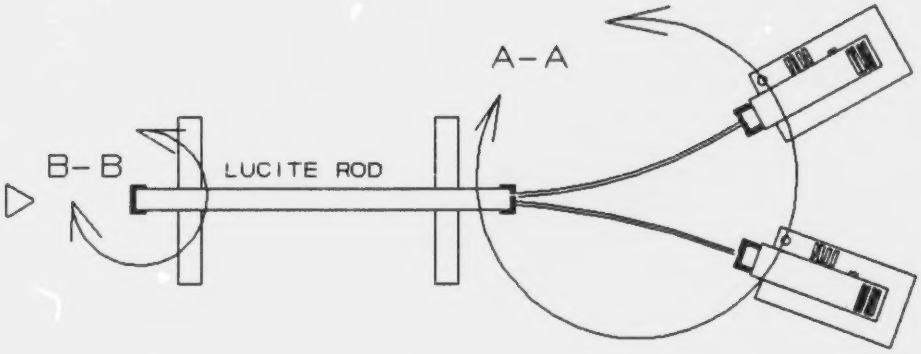

A-A
B-B
LUCITE ROD

Figure A-1-3

Multiplexing Construction

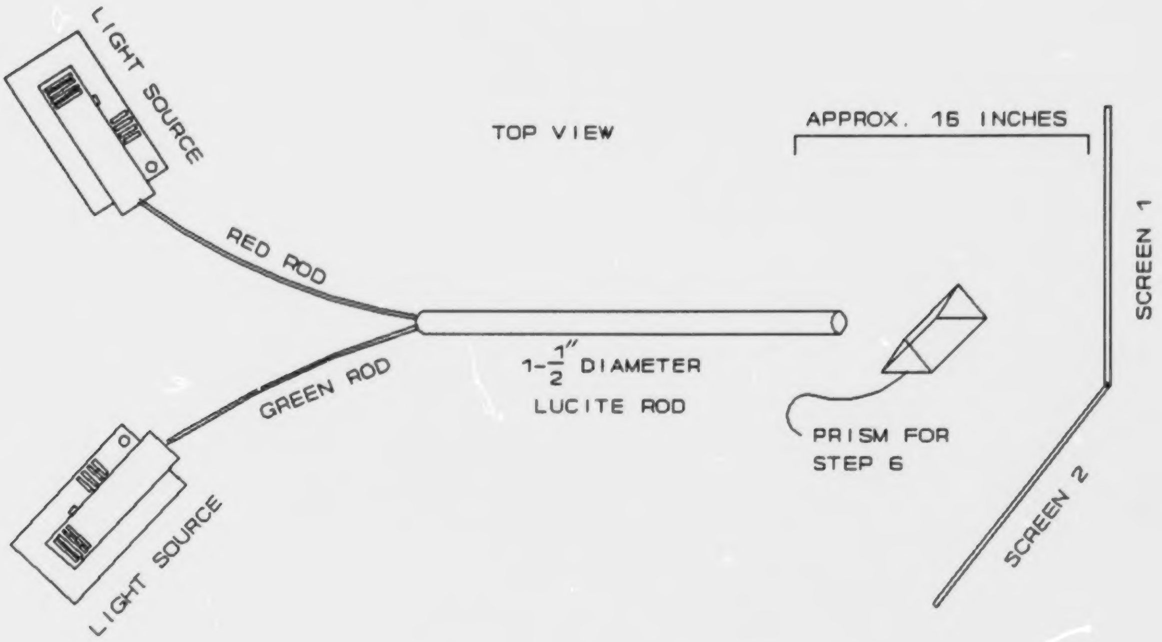

LIGHT SOURCE
TOP VIEW
APPROX. 15 INCHES
SCREEN 1
RED ROD
GREEN ROD
$1\text{-}\frac{1}{2}''$ DIAMETER
LUCITE ROD
PRISM FOR
STEP 6
SCREEN 2
LIGHT SOURCE

Figure A-1-4

Multiplexing by Frequency

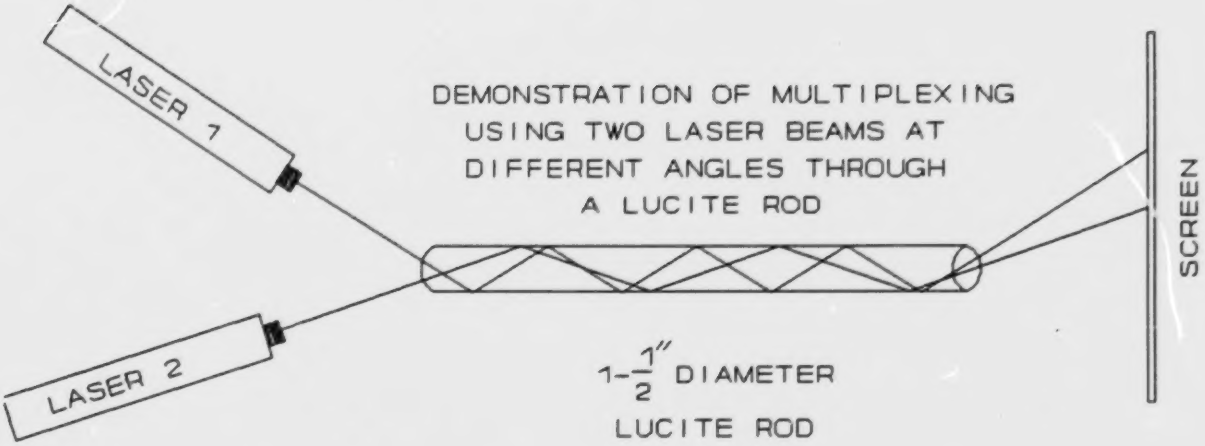

LASER 1
LASER 2
DEMONSTRATION OF MULTIPLEXING USING TWO LASER BEAMS AT DIFFERENT ANGLES THROUGH A LUCITE ROD
SCREEN
1-1/2" DIAMETER LUCITE ROD

Figure A-1-5

Multiplexing by Path Length

ANTICIPATED PROBLEMS: Technological problems in Activity 4 separating colors with a prism.

METHODS OF EVALUATION: Completion of activity lab sheets.

FOLLOW-UP ACTIVITIES: To construct sound systems to communicate (across classroom) via wire, light, and optical fiber.

To investigate the changing of sound to electrical impulse, electrical impulse to photons (light) for transmission by optical fiber, change back to electrical impulse, and then back to sound.

To investigate rail/plane telephone operations, installations and repair (GTE Railphone, GTE Airfone). Communication between computers via modems.

Investigate telecommunication satellites (at NASA). Make and receive phone calls using cellular phones, Airfones, Railfones, etc.

Investigate communication systems and products available for the handicapped. Make a circuit board to simulate modern circuit technology used in electronic components.

Visit AT&T Montgomery plant (or industry with similar production) to see circuits being made for telephones, modems, computers, etc.

Construct a simple circuit board (switch, light, battery, resistor, capacitor) that will light a neon bulb.

**REFERENCES,
RESOURCES,
VENDORS:**

GTE Airfone
2809 Butterfield Road
Oak Brook, IL 60522

AT&T
1 E. Wacker Drive
Chicago, IL

Motorola
1303 E. Algonquin Road
Schaumburg, IL 60196
708-576-2901 (Ed Bales)

Ameritec
30 S. Wacker Drive
Chicago, IL
312-750-5000

Illinois Bell
225 W. Randolph Street
HQ 30C
Chicago, IL 60606
312-727-4755
(Educational Resources, 1-800-972-5069)

Radio Shack or similar local electronics store

The red and green plastic rods were purchased from:

Cope Plastics, Inc.
8110 42nd St. West
Rock Island, IL 61201
1-800-322-1056

The clear 1-1/2" diameter plastic rod was purchased from:

Streamwood Plastics Ltd.
1541 Burgundy Parkway
Streamwood, IL 60103
1-708-289-9190

POST-LAB QUESTIONS

Activity 1

1. What do you see through the end of the rod?

2. What do you see through the lateral sides of the rod?

3. Is the lucite a "conductor" of visible light?

   What evidence suggests your answer?

4. Why could you see objects at the end but not along the lateral surface?

Activity 2

1. What happens to the intensity of the reflected and refracted rays when the dish is rotated?

   ____

2. What is the critical angle?__________________________

3. Describe what happens as you continue to rotate the dish past the critical angle?

   ____

   ____

4. The type of reflection you see after the critical angle is exceeded is:

   ____

PHYS·MA·TECH
AN INTEGRATED PARTNERSHIP

Activity 3

1. Write your observations for (a) white light, (b) green light, and (c) red light.

(a) ____

____

(b) ____

____

(c) ____

____

2. Describe the entire transmission for what you observed on the TV monitor.

____

____

____

____

____

Activity 4

1. What is the appearance of the end of the lucite rod?

   ____

2. What do you see on screen one?

   ____

3. Describe what you see on screen two after you have put the prism in place.

   ____

4. Write in your own words, how this method can be used for multiplexing and how it works.

   ____

   ____

   ____

   ____

   ____

Activity 5

1. What did you see on the screen?

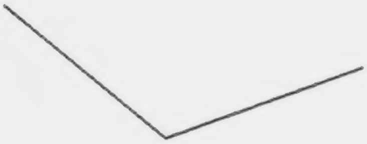
2. Write, in your own words, how this method can be used for multiplexing and how it works.

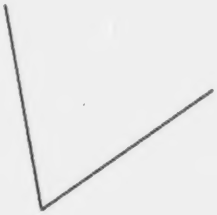
3. Describe what you saw on the end of the rod.

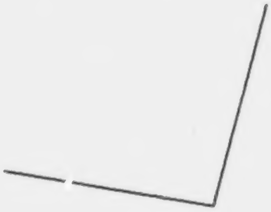
4. Give an explanation for what you saw on the end of the rod.

FIBER OPTICS - MULTIPLEXING MATH WORKSHEET

1. Measure the following angles using a protractor:







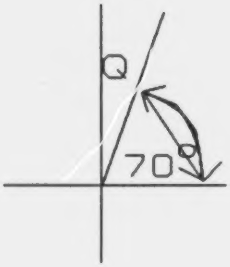
2. Find the sine of each angle measured above.

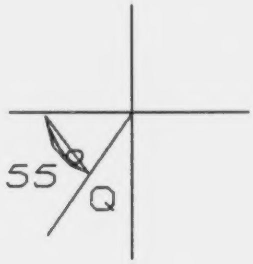
1st angle measure = ______ 1st angle sine = ______

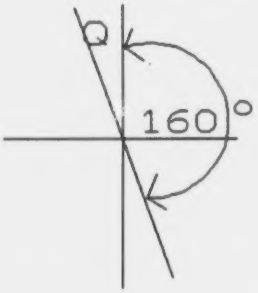
2nd angle measure = ______ 2nd angle sine = ______

3rd angle measure = ______ 3rd angle sine = ______

3. Determine the measure and the sine of each angle.





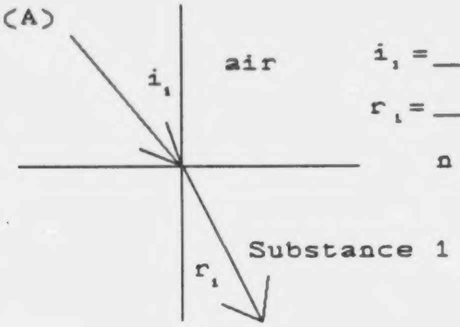


1st angle measure = ______ 1st angle sine = ______

2nd angle measure = ______ 2nd angle sine = ______

3rd angle measure = ______ 3rd angle sine = ______

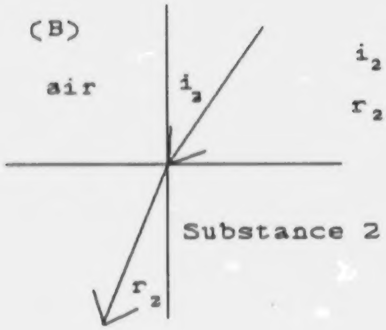
4. Measure each angle i and the angle r. Determine the sine of each angle and determine the index of refraction (n) for each problem. Index of refraction is (n) = (sin i)/(sin r) if the ray is going from the less optically dense to the more optically dense substance.


(A)
i_1
air
r_1
Substance 1

i_1 = _____ sin i_1 = _____

r_1 = _____ sin r_1 = _____

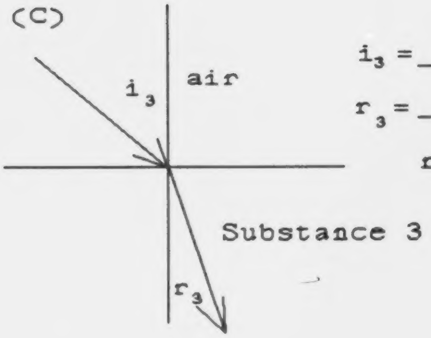
n_1 = _____


(B)
air
i_2
Substance 2
r_2

i_2 = _____ sin i_2 = _____

r_2 = _____ sin r_2 = _____

n_2 = _____

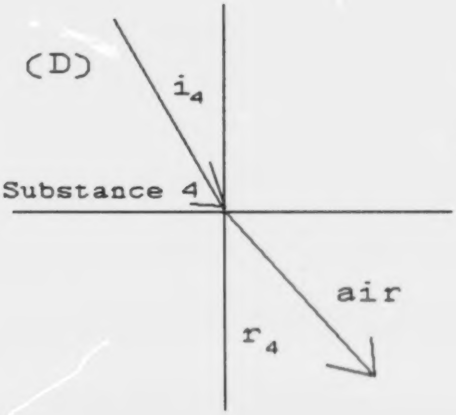

(C)
i_3
air
Substance 3
r_3

i_3 = _____ sin i_3 = _____

r_3 = _____ sin r_3 = _____

n_3 = _____

Note: This ray goes from the more optically dense to the less optically dense substance. Use the reciprocal function.



i_4 = _____ sin i_4 = _____

r_4 = _____ sin r_4 = _____

n_4 = _____

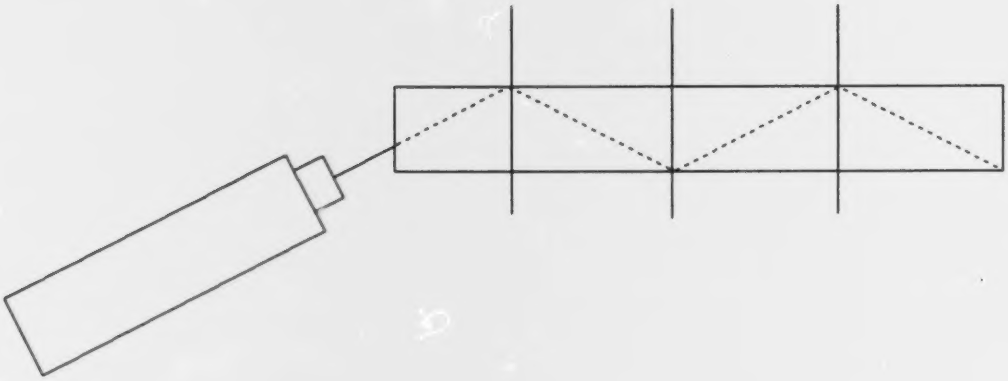
5. Find the velocity of light in each of the four substances in problem (4). The index of refraction is the ratio of the velocity of light in the less optically dense substance to the velocity of light in the more optically dense substance. The velocity of light in air is 3.0×10^8 meters/second.

(A)_______________ (B)_______________

(B)_______________ (C)_______________

MULTIPLEXING - FIBER OPTICS MATHEMATICS WORKSHEET

1. Draw using a protractor or construct using compass and straight edge normal lines at three points of reflection.



At each reflection point:

(a) Measure the angle of incidence.

(b) Measure the angle of reflection.

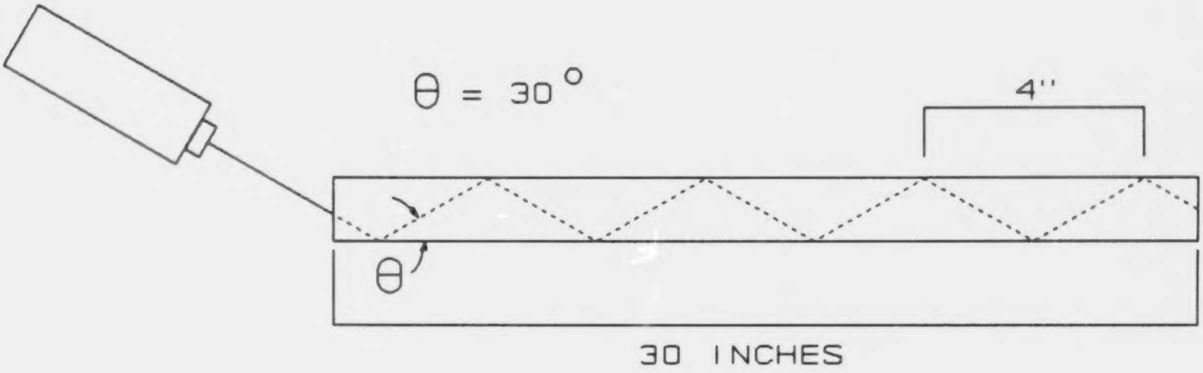
Record these measures on the diagram at the appropriate angles.

Draw a conclusion about the relationship between the angle of incidence and the angle of reflection.

2. Represented in the diagram is a lucite rod with a laser aimed at an angle through the rod.

   (a) Given the first angle, determine the angles of reflection.

   (b) With the information in the diagram, determine the length the beam travels through the rod.



ACTIVITY 2: JACK OF ALL TRADES

TECHNOLOGICAL FRAMEWORK:

Pump Jacks are used in the construction industry for raising scaffolding along the walls of one- and two-story structures.

Hydraulic Jacks are used in many home and industrial applications in which heavy loads need to be lifted short distances. Jack applications quickly lead into the use of hydraulic cylinders.

Screw Jacks are used to lift very heavy loads such as in house moving. An examination of the use of threads is appropriate to this application.

Scissor Jacks (Compound Extension Jacks) are used in maintenance work to lift people or objects great heights.

PURPOSE:

To study actual mechanical advantage, expose students to the operation of simple machines, individually and in combination, simple and compound. Ideal mechanical advantage, actual mechanical advantage, efficiency, work input and work output, and effort force and resistance force will be studied.

ILLINOIS WORKER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their applications to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics:
Lever Jack--work and simple machines, lever, static friction, sliding friction, static equilibrium, torque.

Screw Jack--work and simple machines, screw, static friction, sliding friction, static equilibrium, torque.
Scissor Jack--work and simple machines, screw, static friction, sliding friction, static equilibrium, torque.
Hydraulic Jack--work and simple machines, static equilibrium, lever, fluid dynamics, friction.

Mathematics:
Lever Jack--ratio and proportions, percentage, unit conversion, similar triangles.
Screw Jack--circumference, ratio and proportions, percentage, unit conversion, area of circles, volume of cylinders, similar triangles.
Scissor Jack--circumference, ratio and proportions, percentage, unit conversion, properties of parallelograms, hinge theorem.
Hydraulic Jack--circumference, ratio and proportions, percentage, unit conversion, area of circles, volume of cylinders, similar triangles.

Technology--major and minor diameters, pitch, thread form, multiple threads.

PREREQUISITES: Simple machines, hydraulics; work; read a force gauge, measuring distances; efficiency.

MATERIALS, EQUIPMENT, APPARATUS: Pump jack, General Motors car jack (not a bumper jack), screw jack (trailer jack or house jack), scissor jack (adjustable platform jack), hydraulic jack (combination hydraulic, scissor jack--scaffolding), force gauges, calipers, rulers.

Suggestions: Drill a hole in the end of a jack handle and put a ring in for easy use of force gauge. The same handle could be applied to the lever, screw, and hydraulic jacks.

TIME FRAME: 2-3 class periods.

TEACHING STRATEGIES: Students should rotate through three of these activities (Jack It Up, Pump U-Up Jack, Screw Jack) in groups of eight with a teacher at each station.

Jack It Up. Physics teacher covers mechanical advantage, efficiency of the "pump" scaffolding jacks and discusses their uses. Mathematics teacher reviews percentage, ratio and proportion, conversions, and similar triangles. Technology teacher sets up the scaffolding jacks, demonstrates their uses, and conducts the lab activities.

Pump U-Up Jack. Physics teacher covers static equilibrium, fluid dynamics, efficiency, and simple machines used. Technology teacher discusses the construction and workings of the "Pump U-Up Jack" table (how the telescoping lens work, how to readjust the hydraulic jack to get a higher lift), and hydraulic lifts' industrial uses. Mathematics teacher covers the volume of cylinders and ratio and proportion.

Heavy Screw Jack. Physics teacher covers torque, efficiency, and simple machines. Technology teacher covers major and minor diameters, pitch and multiple threads of screws. Mathematics teacher covers the equilateral triangle components of V-thread screws and reviews the proportions and fraction and decimal skills necessary.

The other two activities need to be begun outside as a class (Jack's Lever Jack and Beam Me Up Jack). After collecting data, smaller groups may be formed to complete analysis.

Jack's Lever Jack. Physics teacher covers simple machines, efficiency and work, and reviews force in classroom. Mathematics teacher reviews percentage, right triangle trigonometry, and proportions. Technology teacher discusses installation, use and safety for lever jack, pump jack, and hydraulic scissor jack.

Beam Me Up Jack. Physics teacher discusses simple machines and reviews torque and efficiency. Technology teacher discusses the construction of the sextant and the uses of scissors jacks in industry. Mathematics teacher covers right triangle trigonometry.

TEACHING METHODOLOGY:

Jack It Up. Have two students stand on a scaffold plank and "step" into the foot strap and "walk" themselves up the wall to demonstrate how the pump jacks work. Remove the plank and place a load on a single jack. Hook a force gauge at the stirrup and measure the force needed to lift the load.

Alternate Method: While the plank and students demonstrating are in place, hook a force gauge into each stirrup and have two students measure the force needed to lift the load.

Pump (clap) U-Up Jack. Using two 2' x 2' sheets of plywood and four sets of telescoping pipes held to the plywood by floor flanges, build a platform for a hydraulic lift to go between. Have a student sit on the top platform. Use a force gauge at the end of the handle to measure the effort force on the handle. Use a digital readout caliper to find the diameters and then determine areas of the master cylinder and the servo-cylinder. See Figure A-2-1, "Hydraulic Jack or Screw Jack."

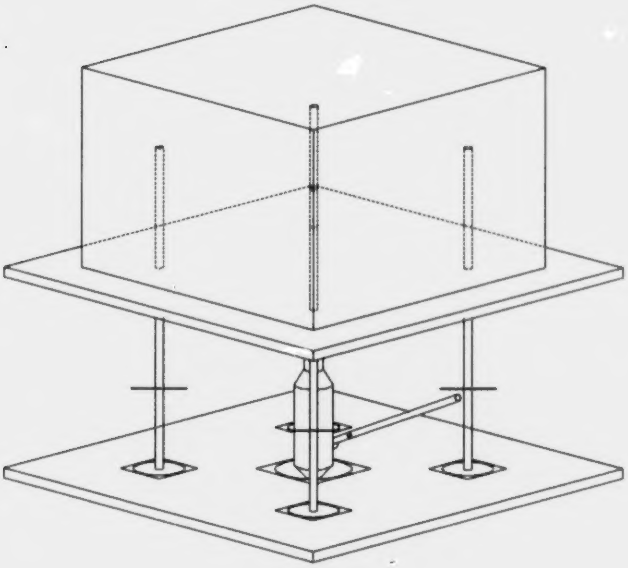


Figure A-2-1

Hydraulic Jack or Screw Jack

Screw Jack. Set up a screw jack on a floor with good support. Have two (or more) strong students place a **heavy** object (weights from the weight room, anvil, etc.) on the telescoping platform (refer to Pump U-Up Jack). Put the screw jack in position to lift the platform. Place the jack rod in the screw. Select a light-weight student to singlehandedly rotate the screw. Measure the distance from the center of the screw jack to the position of applied force (gauge on the rod). Record the weight lifted. Measure the pitch of the thread. Calculate the work input, work output, efficiency, IMA, AMA.

"Zinger"--Screw Jack Extension. This is an extension of the previous lab activity and requires a multiple thread screw jack. After the previous demonstration and calculations, send students in groups to several laboratory stations where heavy screw jacks are set up (only one of which is a multiple screw jack). Do not use the telescoping platform as it inhibits turning the screw jack a complete revolution. Have students repeat the above measurements and calculations and record results on class result sheets (on the blackboard, overhead projector, etc.). Allow questions to lead to examining the multiple thread screw jack.

Jack's Lever Jack. Borrow the keys to the principal's car (if it is General Motors or has the correct type of jack) or use a GM vehicle (not a bumper jack) with a lever jack. Use the manual to determine the weight of the car. Measure the height of a reference point on the bumper. Jack the car up, measuring the force applied to the jack handle (force gauge). Measure the height using the same reference point. Record data to be analyzed with class after students have been to all three stations.

Beam Me Up Jack. In the classroom, the Physics and Technology teachers have demonstrated scissor jack and shown it is essentially identical to a screw jack (one is more conveniently run; the configurations are different). Show the scissor jack is just a system of levels that turns horizontal motion into vertical motion, as a screw jack does.

When students have been split into groups, take each student group out into the parking lot where you have already arranged for a truck with a hydraulic scaffolding to be waiting. (Larger school districts' grounds crew may have one. Check with contractors, painters, or electricians.) Let students examine the scaffolding and watch the working of the scissor jack. Teacher rides to various heights and students record measurements with sextant and a measuring tape held between the teacher and a student standing away from the base on the ground. Use trigonometry functions to compute different heights. (This could also be done by measuring shadows and using similar triangle relationships.

FURTHER FIELDS OF INVESTIGATION:

Screw Jack. Used on its side in cement factory to force things apart. Used in digging ditches. House moving jacks. Cave in supports.

Hydraulic Screw Jack. Scaffolding in warehouses, gymnasiums and on trucks, to retrieve inventory, change light bulbs, work on outside of buildings or trees; installation of kitchen cabinets; barber and dentists' chairs.

Scissor Jack. Fireplace tool. Used in logging industry. Flexible height scaffolding.

Lever Jack. Fire truck ladder, Jaws of Life.

Pneumatic Jack. Warehouse transporting, moving anything heavy.

PROCEDURE: Jack It Up

Pump jacks are an example of a lever system used to lift builders on a scaffold plank. Using a stepping motion, J.T. (our friend, Jack Trades) is able to lift himself along the side of a building.

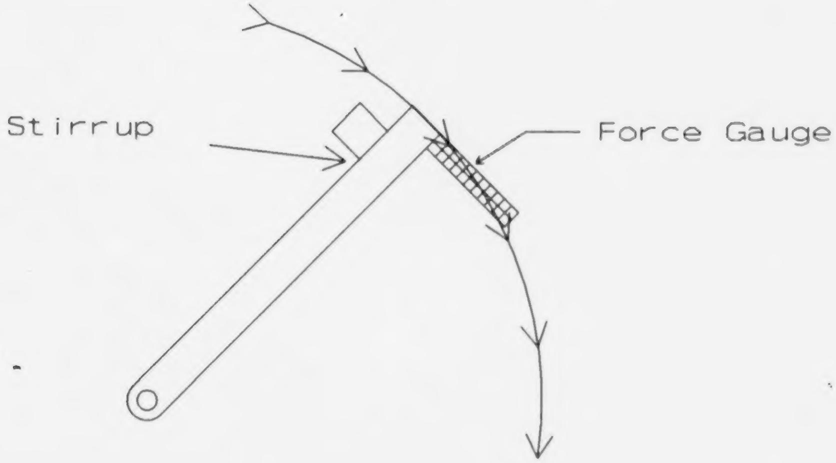
Step 1: J.T. and his friend G.S. (Generic Student) will demonstrate how the jack posts work. J.T. and G.S. stand on the scaffold, place foot in the foot strap of the pump jack, and "walk" their way up the post by "stepping" down and lifting up.

Step 2: Remove the scaffolding from the jacks. Hang 50 lbs. of weight from one of the jacks. Record the weight plus the weight of the jack as F_0.

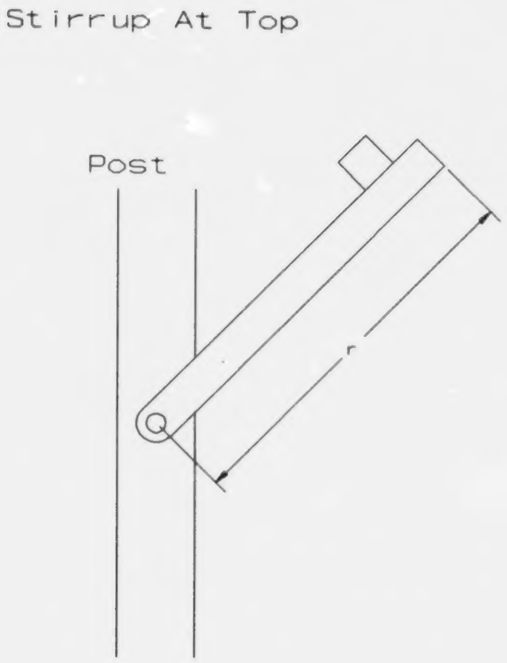
Step 3: Measure the distance the pump jack moves up the beam in one pump. Record this distance as d_0.

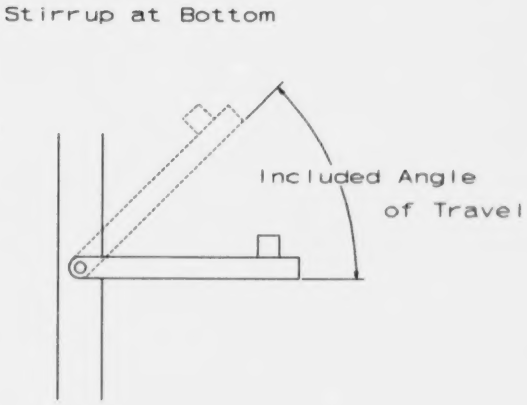
Step 4:

With the pump jack set up as in Step 2, use a spring force gauge to measure the force exerted on the foot stirrup. Hook the force gauge on the stirrup and pull down with a steady force tangent to the arc of the stirrup. Record this force as F_I.



Step 5: To determine the travel distance of the end of the stirrup, measure the included angle of travel.


Stirrup At Top
Post
r


Stirrup at Bottom
Included Angle
of Travel

Use the equation: Distance traveled = $2\pi r - \frac{\textit{Included angle}}{360^\circ}$

Record this distance as d_1.

Complete Data Table A and Results Table A.

Data Table A

d_0	d_I	F_0	F_I

IMA = d_I/d_0 Ideal Mechanical Advantage

AMA = F_0/F_I Actual Mechanical Advantage

W_I = $(F_I)(d_I)$ Work input

W_0 = $(F_0)(d_0)$ Work output

Q = $W_I - W_0$ Loss of energy due to friction

Eff. = W_0/W_I x 100% Efficiency

Results Table A

IMA	AMA	W_I	W_0	Q	Eff

Alternate Method:

Pump jacks are an example of a lever system used to lift builders on a scaffold plank. Using a stepping motion, J.T. (our friend, Jack Trades) is able to lift himself along the side of a building.

Step 1: J.T. and his friend G.S. (Generic Student) will demonstrate how the jack posts work. J.T. and G.S. stand on the scaffold, place foot in the foot strap of the pump jack, and "walk" their way up the post by "stepping" down and lifting up.

Step 2: Two students will use the Fisherman's Scales to measure the force exerted by J.T. and G.S. Hook the force gauges into the straps after J.R. and G.S. remove their feet. (See Figure A-2-1.) Pull on force gauges perpendicular to the lever. Read and record these readings as F11 + F12 = f1.

Step 3: J.T. and G.S. weigh themselves. Their combined weight plus the weight of the scaffold plank plus the weight of the two pump jacks equals F_0.

$$F_0 = W_{G.S.} + W_{J.T.} + W_{plank} + W_{pump\ jacks}$$

Step 4: Measure the distance the pump jack moves up the beam in one pump. Record this distance as d_0. Measure the distance the stirrup end of the jack moves in one pump. Use the same procedure as step 5, page 498. Record this distance as d_I.

Complete Data Table B and Results Table B.

Data Table B

d_0	d_I	F_0	F_I

IMA = d_I/d_0 Ideal Mechanical Advantage

AMA = F_0/F_I Actual Mechanical Advantage

W_I = $(F_I)(d_I)$ Work input

W_0 = $(F_0)(d_0)$ Work output

Q = $W_I - W_0$ Loss of energy due to friction

Eff. = W_0/W_I x 100% Efficiency

Q is the loss of energy due to friction. Since energy is conserved, this will appear as heat.

Results Table B

d_0	d_I	F_0	F_I

Jacks allow a trade of force for distance. You may pull on a handle with a small force and the jack will exert a large force through a small distance.

Screw Jack

This activity will help you understand how a screw jack works. You will be measuring distances, forces, and will be recording the data in a table. Use the telescoping platform to support the weight. (See Figure A-2-2, "Screw Jack.)

Step 1: J.T. (our friend , Jack Trades) and G.S. (Jack's buddy, Generic Student), with additional help if necessary, will place weight(s) on the telescoping platform with the screw jack in place. Record total weight (F_0). **This may be done without the telescoping platform by balancing weights directly on the screw jack.** If the telescoping platform is used, the weight of the platform must be added to the weight on top of the telescoping platform. This would be recorded as F_0.

Step 2: Put the jack handle in place and attach the force gauge to the ring on the end of the jack handle.

Step 3: Measure the distance (r) from the center of the screw jack to the end of the rod where the gauge is connected.

Step 4: Measure the pitch of one thread. (Hint: Measure 10 threads and divide length by 10.)

Step 5: Hold the force gauge and slowly pull tangentially to the circles of rotation, noting the force (F_1), reading from the gauge.

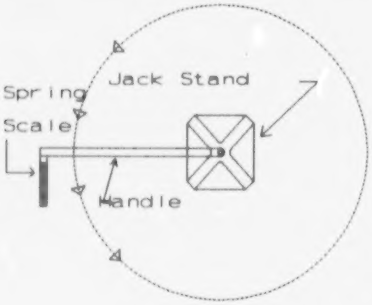


Figure A-2-2

Screw Jack

Complete Data Table C and Results Table C.

Data Table C

Pitch	2π	F_O	F_I

IMA (2π/Pitch) IMA is Ideal Mechanical Advantage

AMA = (F_O/F_O) AMA is Actual Mechanical Advantage

$W_I = (F_I)s\ (2\pi r)$ (for one revolution)

W_I is the Work Input

W_O is the Work Output

$W_O = (F_O)$ (Pitch)

$Q = W_I - W_O)$

Q is the loss of energy due to friction. Since energy is conserved, this will appear as heat.

$$\text{Efficiency} = \frac{W_{out}}{W_{in}} \times 100\%$$

Results Table C

IMA	AMA	W_I	W_O	Q	Eff

Extension of Activity (follow teacher directions if proceeding.

In your assigned group, report to activity stations where you will have a screw jack as worked with previously. Follow the same steps (do not use the telescoping platform as it inhibits complete revolutions) and complete the class chart on the blackboard.

CLASS CHART

Group #_____	Distance moved after each revolution
1st revolution	
2nd revolution	
3rd revolution	
IMA	
AMA	
Efficiency	

Pump (clap) U-Up Jack

Hydraulic jacks to trade force for distance. The handle is pulled down on with a small force and the jack lifts a large force a small distance.

Step 1: J.T. weighs himself or herself. J.T.'s weight plus the weight of the platform plus the weight of the stool if used equals F_0.

$F_0 = W_{J.T.} + W_{platform} + W_{stool}$ (chair)

Step 2: J.T. sits on the top platform of the telescoping table. G.S. (Generic Student) hooks the force gauge into the handle.

Step 3: G.S. pulls on force gauge perpendicular to the handle and reads and records the force (F_I) required to move the handle.

Step 4: Measure and record the distance pulled on the end of the jack handle (d_I).

Step 5: Measure and record the distance the platform rises (d_0).

Complete Data Table D and Results Table D.

Data Table D

d_0	d_I	F_0	F_I

$\text{IMA} = d_I/d_0$ Ideal Mechanical Advantage

$\text{AMA} = F_0/F_I$ Actual Mechanical Advantage

$W_I = (F_I)(d_I)$ Work input

$W_0 = (F_0)(d_0)$ Work output

$Q = W_I - W_0$ (Work lost to friction)

$\text{Eff.} = W_0/W_I \times 100\%$ Efficiency

Results Table D

IMA	AMA	W_I	W_0	Q	Eff

Optional Extension:

Step 6: Use a caliper to measure and record the diameters of the master and servo cylinders of the hydraulic jack. Compute the cross-sectional areas of the cylinders.

Step 7: Determine the Ideal Mechanical Advantage of the lever system and of the hydraulic system of the hydraulic jack. Determine the Actual Mechanical Advantage of the hydraulic jack. Determine the work input and work output of the compound machine. Calculate the efficiency of the system.

Complete Results Table E. Compare the IMA for the entire jack from Results Table E to the IMA from Results Table D.

Results Table E

IMA Lever System	IMA Hydraulic System	IMA Entire Jack	Eff Entire Jack

Beam Me Up Jack

Equipment: Sextant, measuring tape (or long cord marked with appropriate divisions).

Procedures to make Sextant:

Step 1: Glue sextant copy to cardboard.

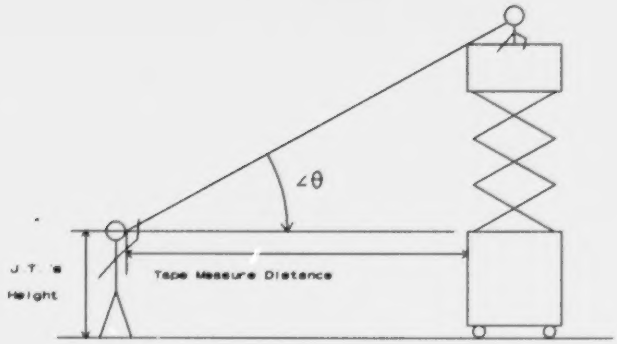
Step 2: Cut along edge and connect brad for plumb line.

Step 3: Connect plumb line with washer for weight.

Using Sextant: J.T.'s teacher rides scaffolding to various heights while holding the end of a measuring tape. This tape will be used to measure the actual height. Observe the working of the hydraulic (pneumatic) jack.

Step 1: G.S. holds the measuring tape on the floor along the line of sight of J.T. This will give you the tape measure distance that J.T. is away from the scaffolding.

Step 2: J.T. stands some distance from the scaffolding, sighting along the sextant up to the teacher who is at a fixed height on the scaffolding. Record the sextant angle in Data Table E. The distance J.T. stands away from the scaffold is recorded as tape measure in Data Table E.



Note: The calculated height plus J.T.'s height should equal the actual height of pneumatic jack and teacher's height.

Opposite side = (Tan θ) (Adj. side)

Data Table E

Sextant Measure	Tape Measure	Trig Function	Calculate Height	J.T.'s Height	Actual Weight

ANTICIPATED PROBLEMS:

Jack It Up. The scaffold plank will have to be high enough off the floor for students to pull down force gauge (fish scale).

METHODS OF EVALUATION:

Completion of work sheets, quiz on jacks, test items.

FOLLOW-UP ACTIVITIES:

Visit an industrial warehouse and observe product handling (how many different kinds of jacks are used). Show students how to change a car tire and discuss placement of jack on the frame. See pneumatic jack in operation in an industrial site and compare to those students built.

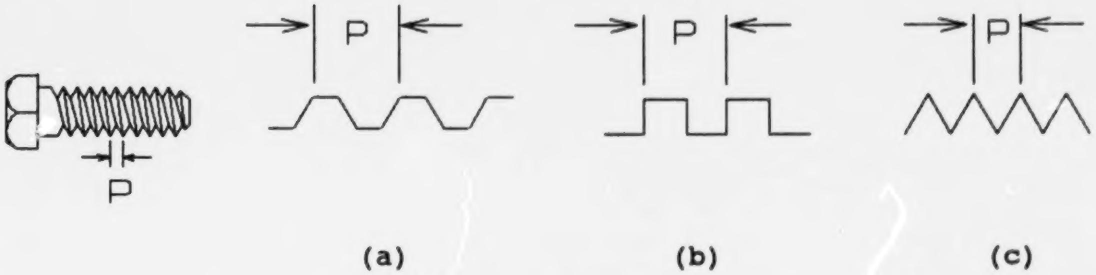
Pneumatic jack--demonstrate a "Hoover-Craft" previously built by teacher team. Discuss industrial uses. Examine how it works. As an extra-credit assignment, allow students to build their own and have a contest to determine best design, most efficient, etc.

REFERENCES, RESOURCES, VENDORS:

Screw jacks can be obtained from a travel trailer dealer. Other materials are found at a hardware store or discount store.

POST-LAB QUESTIONS:

THREADS 'TILL YOU'RE DEAD



The pitch of a screw thread is the distance between corresponding points of two adjacent threads. Three thread types are shown. Match the type of thread with its name:

1. Square Thread__________
2. Acme Thread__________
3. Sharp V-Thread__________

If the distance between the threads is 1/8", the thread is 1/8"-pitch. In 1/8"-pitch thread, there are _____ threads to an inch. Sometimes 1/8"-pitch thread is called 8-pitch thread.

2. Find the pitch of a thread having 12 threads per inch. ______
3. Find the pitch of a screw having 4 1/2 threads per inch. ______
4. Find the number of threads per inch for a 5/8"-pitch screw.______

PITCH = 1 / (NUMBER OF THREADS PER INCH)

5. Number of threads per inch = _____ / _____

Pitch and thread have a reciprocal relationship.

The lead of a screw is the distance advanced in one complete turn.

In a SINGLE-THREADED screw, the LEAD is equal to the PITCH.

In a DOUBLE-THREADED screw, the LEAD is twice the PITCH.

In a TRIPLE-THREADED screw, the LEAD is _____ times the PITCH.

Complete the following chart:

Thread	Pitch	Lead
Single-Thread	$\frac{1}{8}$	
Double-Thread	$\frac{1}{8}$	
Triple-Thread	$\frac{1}{8}$	
Single-Thread		$\frac{1}{4}$
Double-Thread	$\frac{1}{4}$	
Double-Thread		$\frac{3}{8}$
Triple-Thread		$\frac{3}{4}$
Double-Thread		$\frac{3}{32}$

6. What is the lead of a 3/16"-pitch quadruple thread?_____

7. A double-thread screw had 7/32"-pitch. What is the distance advanced after two complete turns?_____

8. A 3/4"-pitch double-thread screw is turned 180 degrees. How far has it advanced?_____

9. How far will a 9-t.p.i. advance in 2 2/3 turns?_____

The CREST of a thread is the top.

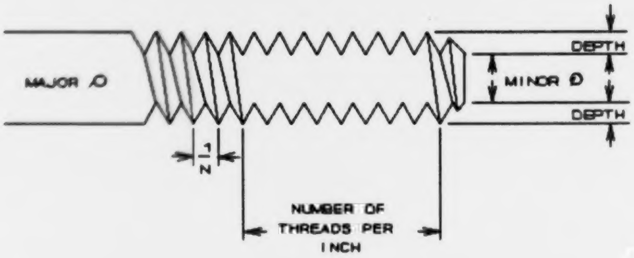
The ROOT of a thread is the bottom.

The DEPTH of a thread is the perpendicular distance between the point and the root.

The MAJOR DIAMETER is the diameter of the stock on which the thread is cut.

The MINOR DIAMETER is the diameter at the roots of the threads.

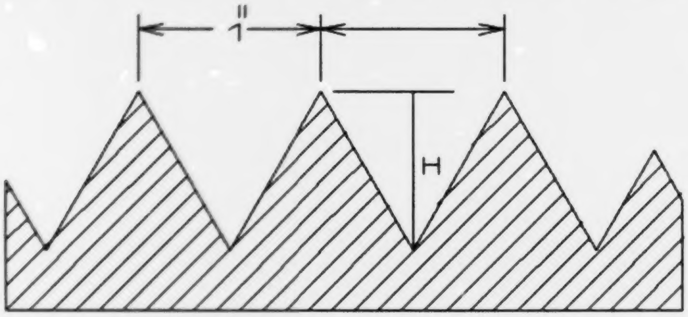
ø - This is the symbol for diameter from the international standards organization.



10. If the MAJOR diameter is 3/4" and the MINOR diameter is 5/"8, what is the "double depth"?_____

11. If the depth is 3/32" and the MINOR diameter is 5/8", what is the diameter of the original stock on which the thread was cut?_____

12. A screw is made from 2 3/8" diameter stock. Its root depth is 3/4". What is the screw's MINOR diameter?_____



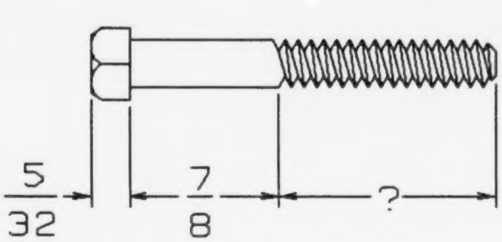
The sides of a V-thread form a 60° angle. If the crests of consecutive threads were connected, an __________ triangle is formed with the two sides of the thread. Each side of the thread is equal to the pitch. Use 30-60-90 relationships to find the following measurements:

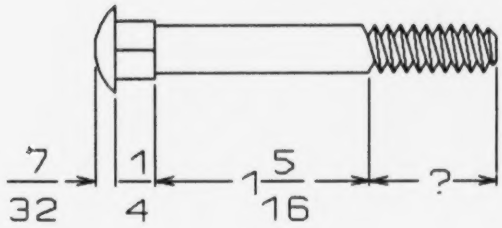
13. Pitch of a V-thread is 1". What is the depth (h in the above diagram) of the thread? (Give exact value.)

14. If the depth of a V-thread is $\sqrt{3}$, what is the pitch?

15. In a V-thread, there are 8 threads per inch. What is the depth of the thread? (Give exact value.)

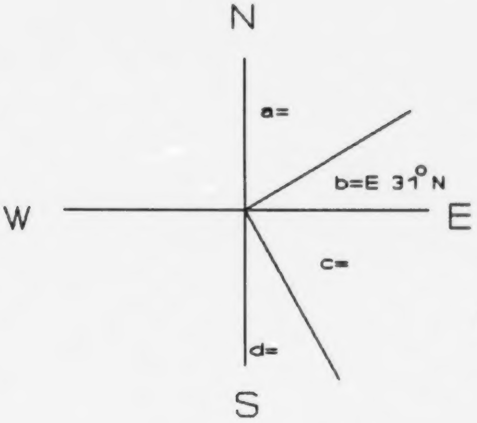
Find the missing lengths. Overall lengths are: A) $2\frac{1}{2}$ B) 4

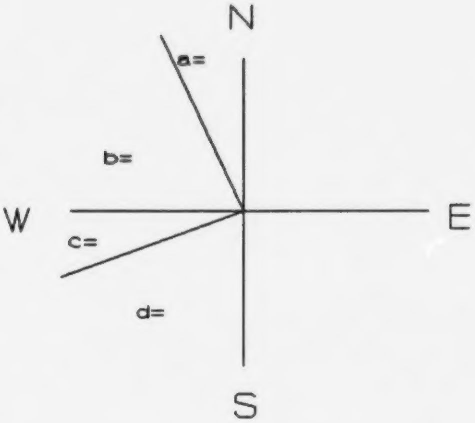


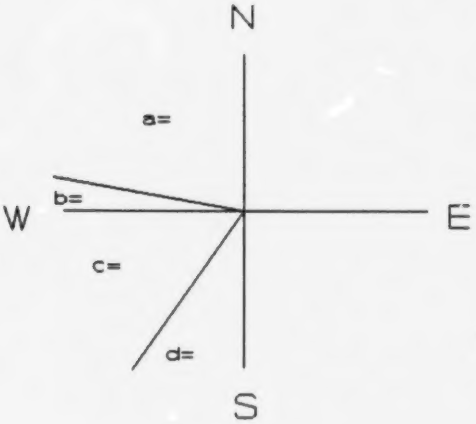


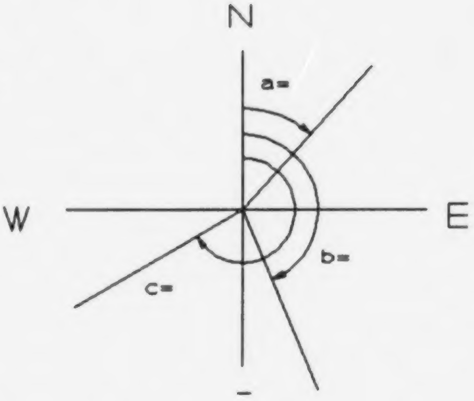
ADDITIONAL POST-LAB QUESTIONS

1. Measure each angle and state its direction. (See example.)

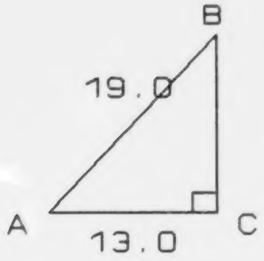

N
a=
b=E 31°N
W
E
c=
d=
S







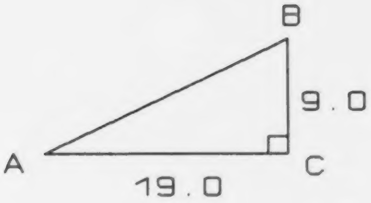
2. Solve the following:



∠ A ____________ ____________

∠ B ____________ ____________

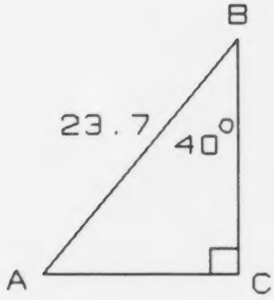
a ____________ ____________



∠ A ____________ ____________

∠ B ____________ ____________

c ____________ ____________



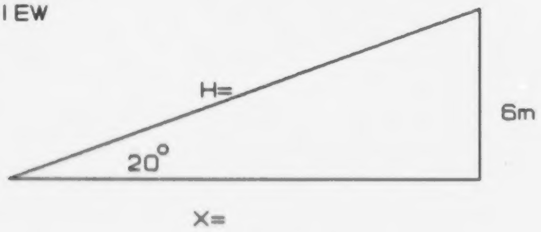
∠ A ____________ ____________

a ____________ ____________

b ____________ ____________

3. Trigonometry Review:

TRIG REVIEW



$\sin 20^\circ = \dfrac{6m}{h}$

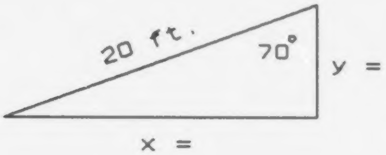
$h = \dfrac{6m}{\sin 20^\circ} = \dfrac{6m}{0.342}$

$h =$

$\tan 20^\circ = \dfrac{6m}{x}$

$x = \dfrac{6m}{\tan 20^\circ} = \dfrac{6m}{0.364}$

$x =$



$\sin 70^\circ = \dfrac{x}{70 \text{ ft.}}$

$x = (\sin 70^\circ)\, 70 \text{ ft.}$

$x = (0.940)\, 70 \text{ ft.}$

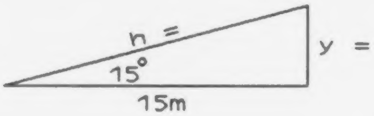
$x =$

$\cos 70^\circ = \dfrac{y}{70 \text{ ft.}}$

$y = (\cos 70^\circ)\, 70\text{ft.}$

$y =$

$y =$



$\cos 15^\circ = \dfrac{15m}{h}$

$h =$

$h =$

$h =$

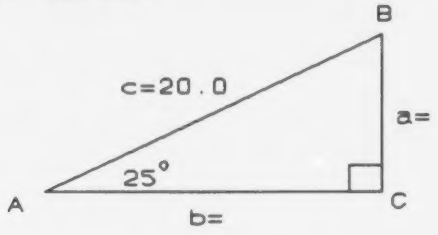
$\tan 15^\circ = \dfrac{y}{15m}$

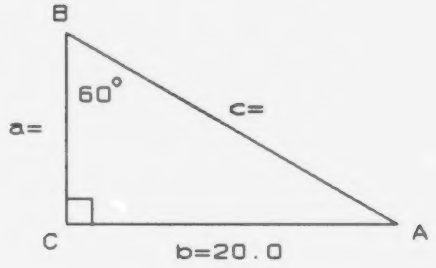
$y =$

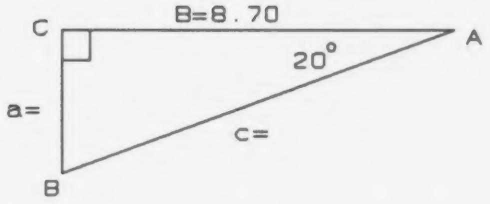
$y =$

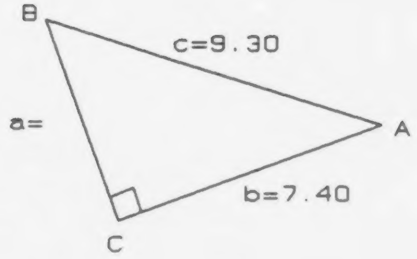
$y =$

4. Solve the following triangles (find the missing angles and sides) using trigonometric ratios.


B
c=20.0
a=
25°
A
C
b=


B
60°
a=
c=
C
b=20.0
A


C
B=8.70
A
20°
a=
c=
B


B
c=9.30
a=
A
b=7.40
C

JACK OF ALL TRADES MATHEMATICS WORKSHEET: USING THE SEXTANT

$$\tan \alpha = \frac{\text{opposite side}}{\text{adjacent side}}$$

Use a scientific calculator or table of tangents to find the missing information in Data Table F.

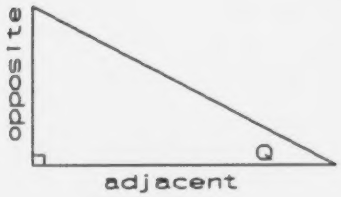
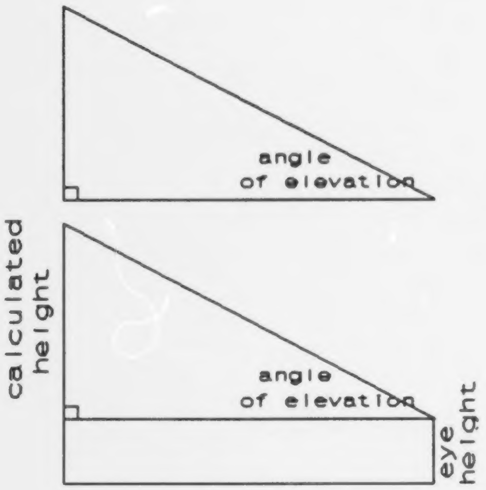


Figure A-2-3
Sample Angle

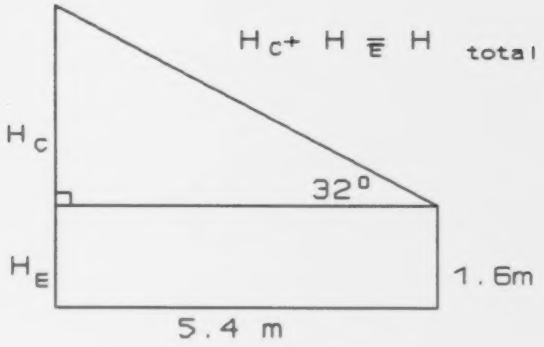
Data Table F

Opposite Side	Adjacent Side	α
4.0 m	9.0 m	
50.5 m		25°
	1.28 dm	20°
22.0 m		35°
	3.25 km	15°

A sextant can be used to measure the angle of elevation. While taking this measurement, most often you will be standing up; therefore, your eye height needs to be measured. Add the "eye level" height to the calculated height for the height of the object being measured.


angle
of elevation
calculated
height
angle
of elevation
eye
height

Find the total height:

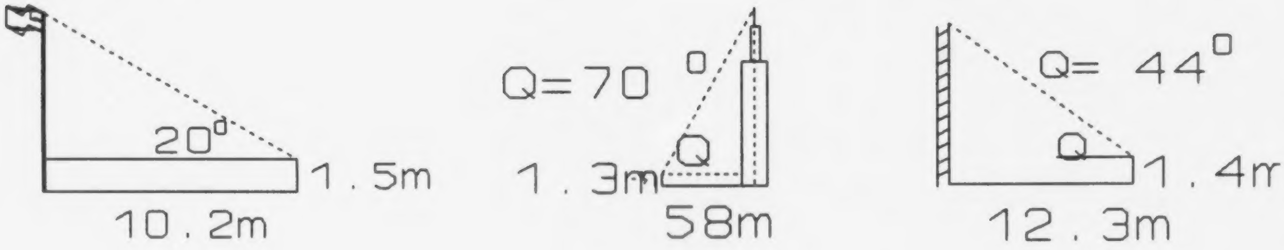

$H_C + H_E = H_{total}$
H_C
32°
H_E
1.6m
5.4 m

Height $_{total}$ = ______

Figure A-2-4

Sample Angle for Calculating Total Height

Find the heights of the objects pictured below:



Flag ______

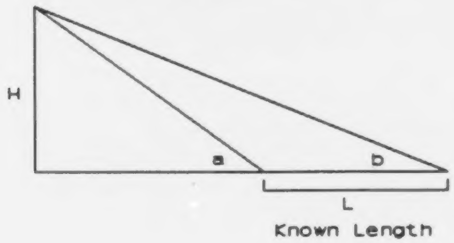
Building ______

Ladder ______

Figure A-2-5

Objects for Height Calculations

It is not always possible to measure the horizontal distance accurately. In the example above, the building sets on the point directly below the top of the building. If the horizontal measurement was taken only to the edge of the building the height calculation would be less accurate. When the horizontal measurement is difficult to make, using the formula developed below will allow for better calculations. It becomes necessary to make two sextant readings and measuring a given horizontal distance (i.e., 10 meters).



$$H = L\left[\frac{(\sin a)(\sin b)}{\sin(a-b)}\right]$$

Figure A-2-6

Calculating Horizontal Measurements

$$\tan a = \frac{H}{x} \qquad \tan b = \frac{H}{x + L}$$

$$x = \frac{H}{\tan a}$$

$$H = \tan b\,(x + L)$$

$$H = \tan b\left[\frac{h}{\tan a} + L\right]$$

$$H = \frac{\tan b \cdot H}{\tan a} + \tan b \cdot L$$

$$x \quad H \cdot \tan a = H \cdot \tan b + L \cdot (\tan a)(\tan b)$$

$$H \cdot \tan a - H \cdot \tan b = L(\tan a)(\tan b)$$

$$H(\tan a - \tan b) = L(\tan a)(\tan b)$$

$$H = L \cdot \frac{(\tan a)\ (\tan b)}{\tan a - \tan b}$$

This formula could be used to find H.

Using Trigonometry Identities we re-write the equation in terms of sine.

$$\tan = \frac{\sin}{\cos}$$

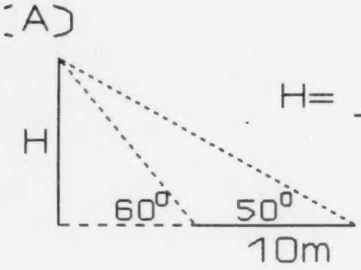
$$\frac{(\tan a)\cdot(\tan b)}{\tan a - \tan b} = \frac{\dfrac{\sin a}{\cos a}\cdot\dfrac{\sin b}{\cos b}}{\dfrac{\sin a}{\cos a} - \dfrac{\sin b}{\cos b}}$$

$$\frac{\dfrac{\sin a \cdot \sin b}{\cos a \cdot \cos b}}{\dfrac{\sin a \cdot \cos b - \sin b \cdot \cos a}{\cos a \cdot \cos b}}$$

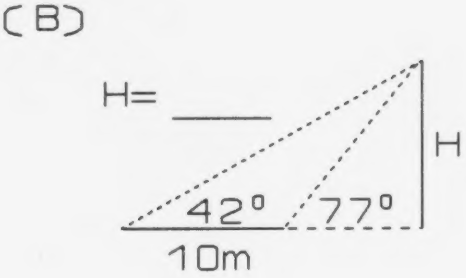
$$\frac{\sin a \cdot \sin b}{\sin a \cdot \cos b - \sin b \cdot \cos a}$$

$$\sin (a - b) = \sin a \ \cos b - \sin b \ \cos a \qquad \frac{\sin a \cdot \sin b}{\sin (a - b)}$$

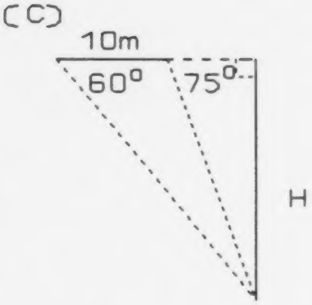
Find the height (H) in each of the following:



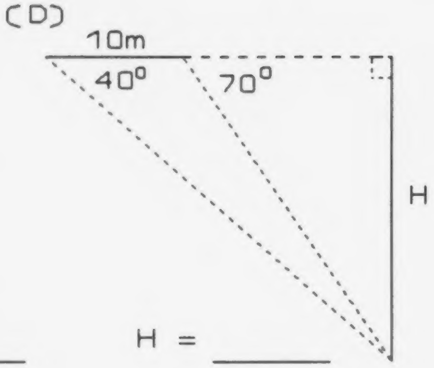
H= _____



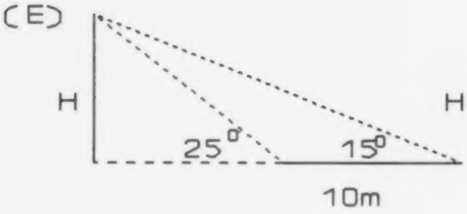
H= _____



H = ______



H = ______



H = ______

Figure A-2-7

Sample Angles

Using the Sextant to find Heights:

1. Use the sextant construction worksheet to make a sextant.
2. Measure 10 meters of string.
3. Measure your "eye-level" height.
4. Identify (with your class or group, as per teacher instructions) six objects to measure the height of.

   Suggestions: flagpole, school building, tree, lamp pole, baseball backstop, t.v. antenna on a house roof, church steeple.

5. Position yourself to take your first sextant measurement. Some things to consider while selecting your position of measurement are:

   (a) Level ground between the base of the object being measured and your position will increase the of the measurement.

   (b) The two sextant measurements should not be the same. Your equipment is not very sophisticated; therefore, you will need to be fairly close to the object to get different sextant measurements at only 10 meters apart.

   (c) Stand straight so your eye height is consistent with each measurement.

6. Measure and record the first angle measurement.
7. Back away 10 meters. Make and record the second angle measurement.
8. Repeat steps 5-7 for all objects selected for measurement.
9. Draw diagrams of objects measured including the angle measurements taken.
10. Calculate the heights of the objects and complete Data Table G.

DIAGRAMS OF OBJECTS BEING MEASURED
(with angle measurements)

Object 1 ________________

Object 2 ____________

Object 3 ____________

Object 4 ____________

Object 5 ____________

Object 6 ____________

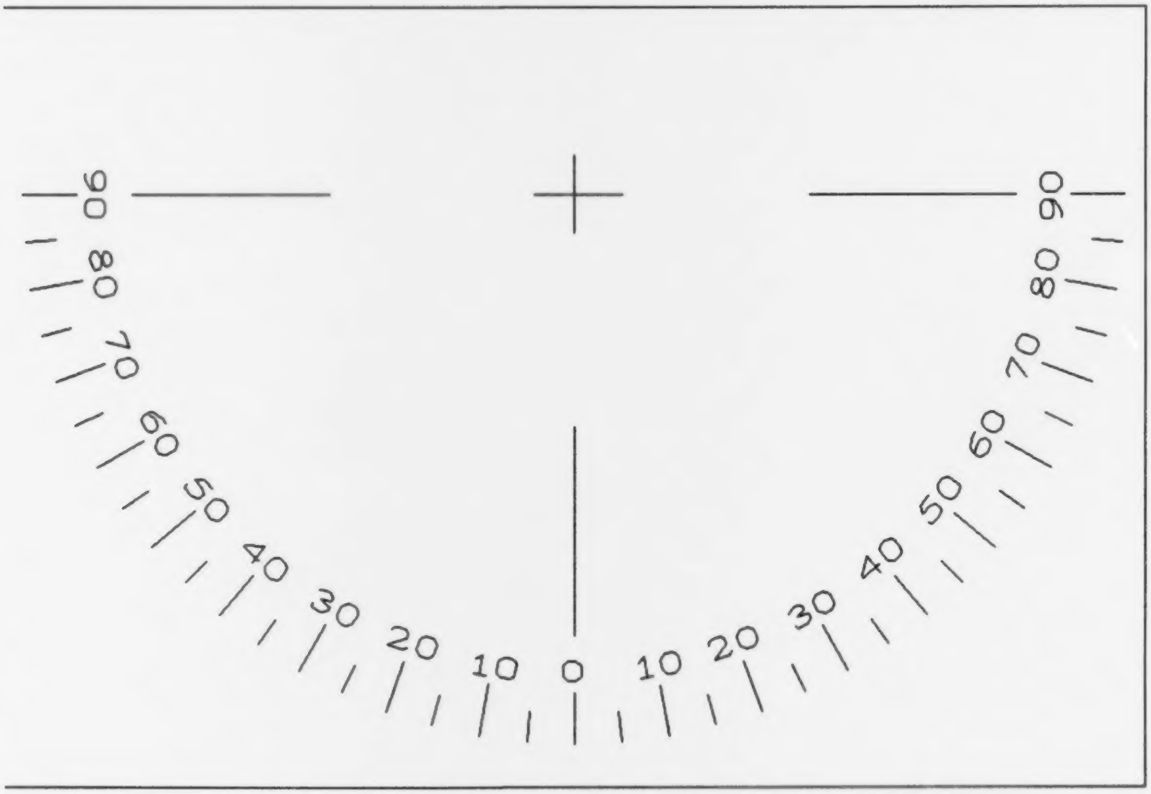
Data Table G

HEIGHTS FOUND USING SEXTANT MEASUREMENTS

OBJECT	1st ANGLE	2nd ANGLE	L	HEIGHT
			10 m	
			10 m	
			10 m	
			10 m	
			10 m	
			10 m	

SEXTANT CONSTRUCTION

Below is a sextant face which may be copied and used by each student to quickly construct his/her own sextant. Place a soda straw along the long edge of a 5-1/2" x 9" piece of corrugated cardboard (such as used for cartons). This straw will form the sighting scope. Next, glue the face on the cardboard making sure the line provided is parallel with the scope (artists' spray adhesives work well for this purpose). At the center of the sextant scale, poke a hole through the cardboard with a nail, awl, or other suitable device. Place a seven-inch-long string through the hole and tie a washer to both ends. Allow the string to hang down over the face of the sextant to indicate the angle of inclination of the instrument.



ACTIVITY 3: INERTIA WELDER (Friction Welding)

TECHNOLOGICAL FRAMEWORK: Welding of wheel rims to form an air-tight seal, allowing for tubeless tires.

PURPOSE: To weld two metal surfaces together by the heat produced from friction.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--friction, heat, and kinetic theory.

Mathematics--measurement, percentages, area.

Technology--use of an engine lathe, facing stock, mild steel.

PRE-REQUISITES:
Friction
Heat and kinetic theory
Basic engine lathe operation
Safety considerations

MATERIALS, EQUIPMENT, APPARATUS:
Engine lathe
3/8" mild steel stock

TIME FRAME: One or two class periods (depending on the size of the class) to be run in conjunction with other activities.

TEACHING STRATEGIES:

Demonstration in small groups, using an engine lathe (metal cutting lathe).

Teacher (or student[s]) should precut two 2 1/2" lengths (long enough to bottom out the chuck) of 3/8" hot rolled mild steel for each demonstration. Face each piece to ensure smooth contact. Run the engine lathe at high speed and slowly push the tail stock until contact is made. When the contact area glows red hot, turn off the engine lathe. Remove the steel with tongs and cool slowly. When steel is cool to touch, allow students to examine the weld. Conduct destructive testing by hand strength or placing steel in vice and tapping with a hammer. Have students examine the weld ends.

This weld is not ideal. The stock continues to turn as the lathe slows down, thus destroying the weld just made. It is still strong enough to demonstrate the process. We could not break it with our hands, though it broke easily when the steel was held in a vice and tapped with a hammer. Looking at the cross section, it is easy to see the weld was better in the center, and weakened as the radius increased. When demonstrating with unfaced steel, a weld will probably not be successful.

TEACHING METHODOLOGY:

A lab demonstrated in the machine shop, using an engine lathe which will be presented to two or three students at a time by the Technology teacher.

Suggestions: This lab could be demonstrated alternating with other welding activities. A visit to an industrial site where friction welding is used should be an integral part of this lab. The weld made on the engine lathe is not as dramatic as the welds using this method used in industry. This method of welding is commonly used in making wheels for tubeless tires.

FURTHER FIELDS OF INVESTIGATION:

Industrial production welding, i.e., the making of wheel rims.

PROCEDURES:

Friction welding will be demonstrated by teacher(s) to small groups (2 or 3 students at a time).

Measure and record the length and the diameter of each piece of steel.

Wear your safety goggles.

You will observe the following steps:

Step 1: 2 1/2" of 3/8" diameter hot rolled steel will be mounted in the engine lathe head stock. Two pieces will be faced off.

Step 2: Each piece of faced off steel will be mounted, one in the head stock and one in the tail stock.

Step 3: The engine lathe will be set for high speed and the tail stock will be advanced toward the head stock until contact is made.

Step 4: You will hear the contact being made. You will see a color change in the steel.

Step 5: Engine lathe will be turned off, steel carefully removed and cooled.

Step 6: Measure and record the length and diameter of the steel.

Step 7: You will be able to test the strength of the weld.

Step 8: Assuming the weld is circular, measure the diameter of the weld after breaking.

Step 9: Repeat steps 2 through 5 with rough cut steel rounds.

Step 10: Complete the Post Lab Questions: "Observations of Friction Welding."

ANTICIPATED PROBLEMS:

Be sure safety procedures are observed. Students will wear protective eye cover and should stand at the ends of the operating lathe. Tail stock pressure should be increased slightly as the lathe is shut off to improve the weld.

METHODS OF EVALUATION:

Completion of worksheet, discussion of observations.

FOLLOW-UP ACTIVITIES:

Students could be allowed to make their own friction welds if time is allotted for training on the engine lathe. Several welds could be made, adjusting the size of the steel, the length of time the steel is kept "red rod," or the speed of the engine lathe. Students could be asked to record the time it takes to make the weld under these different situations.

Testing the strength of the welds is another activity that could be planned.

Industrial sites where friction welding is used, such as making wheels, should be visited.

REFERENCES, RESOURCES, VENDORS:

Caterpillar Tractor
P.O. Box 348
Aurora, IL 60507
(708) 859-5884
Gerry Schmidt, Training Manager

POST-LAB QUESTIONS:

OBSERVATIONS OF FRICTION WELDING

1. Measure stock before and after weld. Record measurements in the table:

Measurements	Length	Diameter
1st Piece		
2nd Piece		
Welded Piece		

2. What is the result of facing off the ends of the steel piece?

3. What is mild steel?

4. How would you describe the sound made when the pieces of steel made contact?

5. Describe the color(s) you saw. (Use a color temperature guide to state an approximate temperature.)

6. Were you able to break the weld?

   If so how?

   Describe the force applied to the weld.

7. What was the diameter of the weld after breaking?

8. How could this weld have been made stronger?

INERTIA WELDING MATHEMATICS WORKSHEET

An engine lathe has a stepped pulley system which transfers power from the motor at a variety of speeds. Figure A-3-1, "Stepped Pulley System," is a simplified diagram of such a system.

To find the length of the belt, determine the lengths of the common tangents and the lengths of the arcs on each pulley wheel.

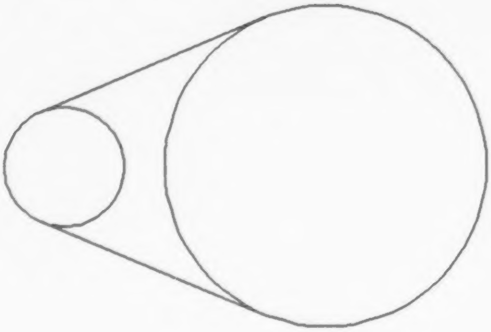


Figure A-3-1

Stepped Pulley System

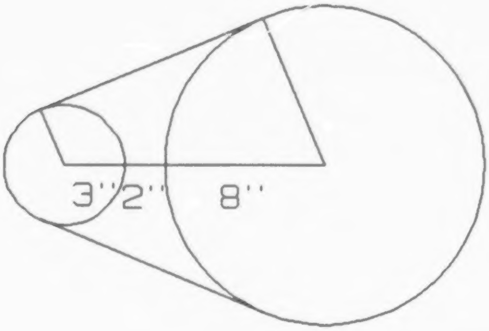


Figure A-3-2

Radii

In Figure A-3-2, "Radii," the radii of the pulleys is given as 3 inches and 8 inches. The distance between the centers is 13 inches.

To find the length of the common tangent, a parallel segment is drawn from the center of the smaller pulley (Figure A-3-3, "Parallel Segment").

Find the length of the short side of the right triangle (the value of **n**).

1. Use the Pythagorean Theorem to find the length of the common tangent.

   (a) n = _______

   (b) L = _______

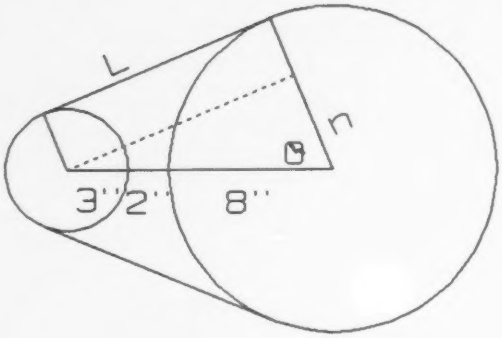


Figure A-3-3

Parallel Segment

Find the measure of θ using right triangle trigonometry.

(c) θ = _______

Extend the line of centers so that it includes the diameter of the smaller pulley.

Draw the radii to the lower common tangent. Note that the central angles between the line of centers and the radii to the lower common tangent is equal to θ. The central angle of belt in contact with the small pulley is 2θ.

Find the length of belt in contact with the small pulley.

(d) arc_1 = ________ Hint: $\frac{2\theta}{360} \cdot$ (circumference)

$$\frac{2\theta}{360} \cdot d\pi$$

Find the central angle of belt in contact with the large pulley. (The central angle of the arc not in contact is 2θ.)

Find the length of belt in contact with the large pulley.

(e) Central angle = ______ arc_2 = ________

(f) Determine the total length of the belt. __________

2. Draw a figure to represent another pulley system where the pulleys have diameters of 4 inches and 20 inches and the distance between centers is 16 inches. Determine the length of the belt for this system.

3. Draw a figure to represent a pulley system where the pulleys have equal diameters and the distance between the centers is 10 cm. The function of this kind of pulley system is only to transfer power. The length of the belt measures 38.86 cm. What is the diameter of the pulleys?

4. While operating an engine lathe the belt breaks. List three ways you could find the length of the belt in order to know what size belt to replace it with.

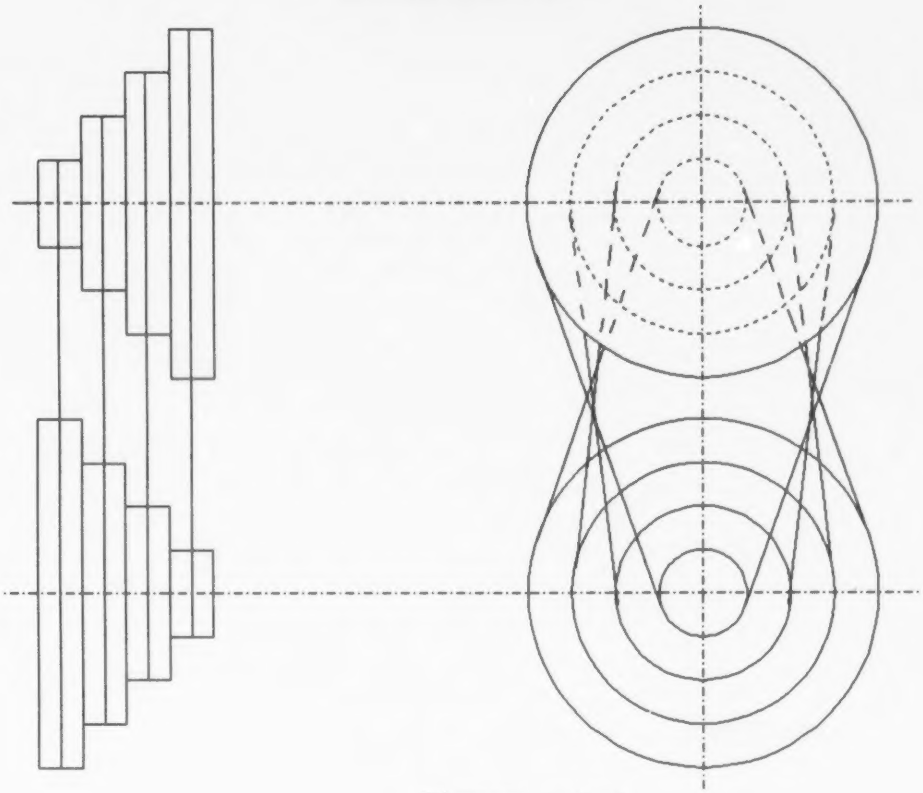


Figure A-3-4

Front View and Side View of Stepped Pulley System

The purpose of a stepped pulley system in an engine lathe is to allow us to change the speed at which the material turns. The motor drives the primary pulley which causes the belt to turn the secondary pulley. In Figure A-3-4, "Front View and Side View of Stepped Pulley System," the pulleys are identical. Use Figure A-3-4 and the following information to answer the questions. The diameters of the steps are 1 inch, 2 inches, 3 inches, and 4 inches.

5. When the primary pulley has a diameter of 1 inch the secondary pulley has a diameter of 4 inches. Complete the table:

Primary Pulley	Secondary Pulley
1 inch	
	3 inches
	2 inches
4 inches	

6. If the primary pulley's diameter is 1 inch and rotates 60 times, how many revolutions will the secondary pulley make?

7. If the secondary pulley's diameter is 3 inches and the primary pulley rotates 300 times, how many revolutions will the secondary pulley make?

8. If the belt is on the smallest diameter pulley, the secondary pulley is turning at:

   (a) its fastest speed

   (b) the same speed as the primary pulley

   (c) its slowest speed

   (d) four times the speed of the primary pulley

9. If the belt is on the 1-inch primary pulley and rotates 2/3 turn (240°), how many degrees will the secondary pulley turn? What fraction of a revolution will this be?

10. The belt is on the 2-inch step of the primary pulley rotating at 1800 rpm. What is the rate of the secondary pulley?

11. The belt is on the 3-inch secondary pulley, rotating at 1200 rpm. What is the revolutions per minute of the primary pulley?

12. Mounted in the lathe is 1-inch diameter stock. If the belt is on the 2-inch primary pulley, rotating at 1800 rpm, what is the rate (in feet per minute) that the stock passes the cutting tool?

13. Mounted in the lathe is 3-inch diameter aluminum stock. If the ideal cutting speed is 950 feet per minute and the motor turns at 1800 rpm, what step should be used to come closest to the ideal cutting speed? (Give diameters of both primary and secondary pulleys.)

ACTIVITY 4: ELECTROMAGNETIC DOOR CONTROL

TECHNOLOGICAL FRAMEWORK:

There are many common uses of magnetic relays in electrical systems found in industry as well as in the home. An example of such an application would be in the use of low-voltage lighting used in many buildings. Safety switches allow a machine operator to operate high voltage and high current switches remotely.

Heat expansion is used in metallic temperature sensors. An example is the home thermostat. Also, expansion of materials due to temperature changes is accounted for in construction of roads, bridges, and even the laying of floor materials in construction work.

A device which uses a combination of these two concepts is the fire door system found in schools and other public buildings. The rise in temperature causes a coil of metal to expand and in the process activates an electromagnet which releases the fire door.

PURPOSE:

Construct a working model of a heat-sensitive door release to study electromagnets and heat expansion of solids.

ILLINOIS LEARNER OUTCOMES:

As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:

Physics--thermal expansion, magnetism and magnetic fields, direct current circuits.

Mathematics--proportions (Expansion is directly proportional to the heat, proportionality constants.) Also this is a good demonstration of the Hinge Theorem.

Technology--remote control using magnetic relays, temperature sensors using expansions of metals.

PRE-REQUISITES: Thermal expansions of solids.

MATERIALS, EQUIPMENT, APPARATUS:

Metal contact plate (ferrous metal), spring-loaded hinges, wall and door frame mockup. Inexpensive thermostat (Honeywell LR-1620). 22-gauge bell wire or magnet wire. Dry cell holder, 1-1/2 volt dry cell (a power supply may be substituted for the cell), 1/4" x 4" lag bolt, wire lead, single pole switch, hair dryer (1000 watt min.). Force gauge if doing activity to measure force needed to hold door open.

TIME FRAME: Two class periods

TEACHING STRATEGIES:

Activity can take place in Physics or Technology laboratory.

Each group (2 students suggested) will build their own mockup. Teachers will pre-construct door frames and right-angle walls (one per group).

Doors are made from wood or particle board with a ferrous metal striker plate for the magnet.

Be sure the magnet wire is sufficiently long to connect to the thermostat and does not inhibit the closing of the door.

Prepare pre-cut materials needed for each mockup. Package materials with two spring-loaded hinges (cabinet or screen door spring hinges are suggested), lag bolt, dry cell, thermostat, lead wire, switch, striker plate. Students will wind (200 or more windings on the lag bolt) their own magnet, hook up and test the heat sensor door release. The teacher needs to bypass the range control of the thermostat. This is accomplished by cutting the white wire lead at the ranging device and reconnecting it to the white terminal on the base plate at the rear of the thermostat. (The teacher may choose to pre-assemble the wall portion of the mockup, placing the thermostat in an enclosure with only the two wire leads extending through the enclosure. The enclosure must be provided with several air holes to allow heating of the thermostat. This allows the student to speculate as to why and how the heat provided releases the door.)

TEACHING METHODOLOGY: Lecture material covers heat expansion (bi-metallic strips). Electromagnets and direct current circuits lectures could be used as a pre- or post-lab. Student lab activity is building the electromagnetic door closer with a heat sensor.

FURTHER FIELDS OF INVESTIGATION: Fire hood which also activates fire extinguisher in commercial kitchens. Fire door system in schools, businesses, and industries.

PROCEDURE:

Note: A current in a wire sets up a magnetic field which causes the magnetic poles to align. Iron (in the bolt) becomes a magnet which holds a metal door open. Heat will cause the metal in the thermostat to expand and put the switch in the "Off" position, thus closing the door. The following procedures will guide you in constructing a working model of a fire door.

Procedure 1: Given pre-cut materials, assemble a door frame with wood screws. (See Figure A-4-1, "Electromagnetic Door Control.")

Procedure 2: Attach door to frame with spring-loaded hinges.

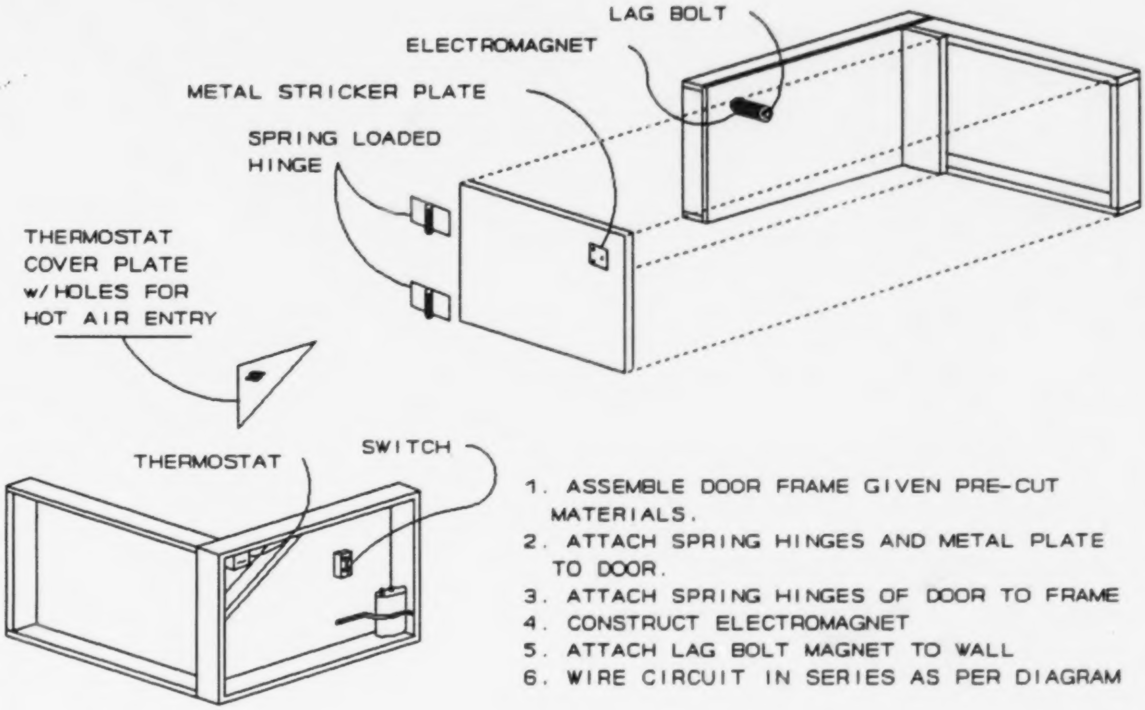
Procedure 3: Construct the electromagnet. Wrap 200 or more turns of magnet wire around the lag bolt. (Do not wrap wire around the first 3/4" of the threads.)

Procedure 4: Turn lag bolt magnet into the pre-drilled hole in the wall.

Procedure 5: Connect thermostat in series with the dry cell, electromagnet, and switch. (See Figure A-4-2, "Schematic for Electromagnetic Door.")

Procedure 6: Use the hair dryer to heat the thermostat and patiently observe the results.

ANTICIPATED PROBLEMS:	Students need to know to leave enough length of wire to make connections. Tension in the spring hinge may need to be adjusted.
METHODS OF EVALUATION:	Have students explain the physics behind the magnet and the heat expansion soil of the thermostat. Observe the mercury switch and draw conclusions.
FOLLOW-UP ACTIVITIES:	Draw a diagram of the door mockup using a smoke detector as the activating sensor. Study or build pressure sensor activated electromagnetic door. Pressure sensors may be obtained from musical toys. Determine rotational acceleration and velocity of the door at various points. Measure the force required to hold the door open. Prescribe different turnings on the magnet and measure the current used by each lab group. Determine the magnetic force. Measure the voltage at different times. Look at current drain; this will be different with each magnet. This will lead to discussion about predicting how long the battery will last, emergency lighting systems, etc. Show or discuss how a gravity model fire door used to work.
REFERENCES, RESOURCES, VENDORS:	Hardware store Radio Shack


LAG BOLT
ELECTROMAGNET
METAL STRICKER PLATE
SPRING LOADED HINGE
THERMOSTAT COVER PLATE w/HOLES FOR HOT AIR ENTRY
THERMOSTAT
SWITCH

1. ASSEMBLE DOOR FRAME GIVEN PRE-CUT MATERIALS.
2. ATTACH SPRING HINGES AND METAL PLATE TO DOOR.
3. ATTACH SPRING HINGES OF DOOR TO FRAME
4. CONSTRUCT ELECTROMAGNET
5. ATTACH LAG BOLT MAGNET TO WALL
6. WIRE CIRCUIT IN SERIES AS PER DIAGRAM

Figure A-4-1

Electromagnetic Door Control

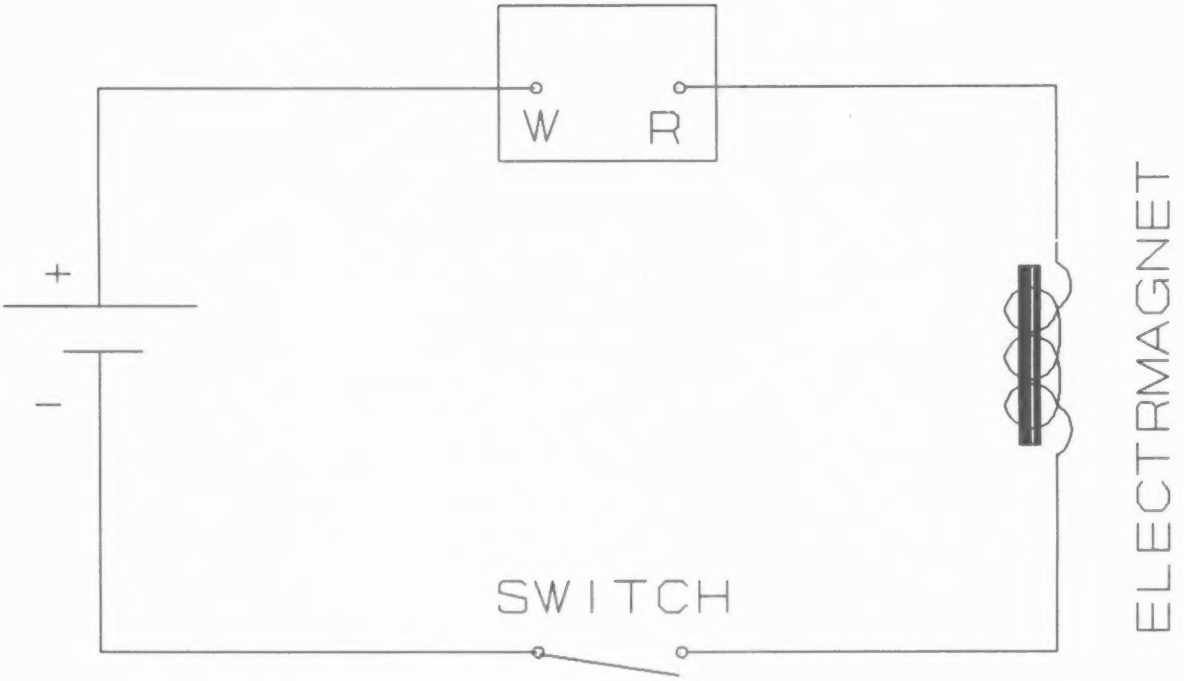

W
R
+
–
ELECTRMAGNET
SWITCH

Figure A-4-2

Schematic for Electromagnetic Door

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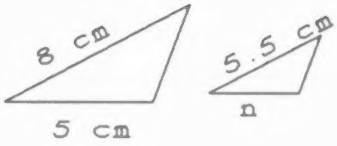
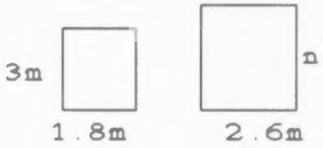
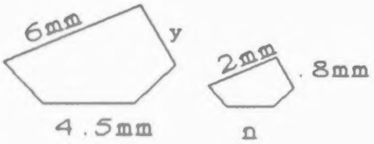
ELECTROMAGNETIC DOOR MATHEMATICS ACTIVITY

Similar polygons have congruent corresponding angles and corresponding sides in proportion. For the similar figures, find the missing terms.


8 cm
5 cm
5.5 cm
n




6mm
y
4.5mm
2mm
.8mm
n

$\frac{8}{5.5} = \frac{5}{n}$

$\frac{3}{n} = \frac{1.8}{2.6}$

____ = ____

____ = ____

n = _____

n = _____

n = _____

y = ______

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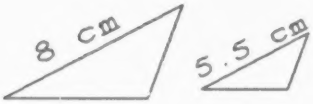
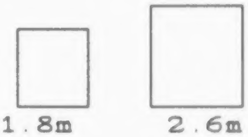
Aurora West High School
Activity 4
Electromagnetic Door Control

In similar figures corresponding segments are directly proportional. $\Delta ABC \sim \Delta A'B'C'$ The constant of proportionality is the value that satisfies k in the equation: $m(AB) \cdot k = m(A'B')$. The reciprocal of k (=K) satisfies the equation: $m(AB) = K \cdot m(A'B')$. Find k, the constant of proportionality, for the polygons.



8 k = 5.5

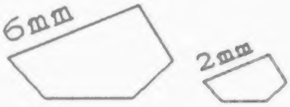
k = ____



1.8 k = 2.6

Do not round.
Write the value of k
as a fraction.

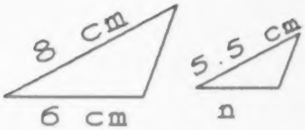
k = ____

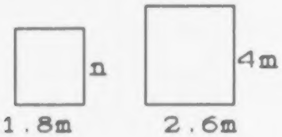


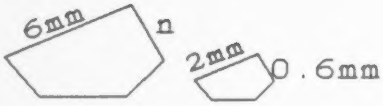
Do not round.
Write the value of
as a fraction.

k = ____

Use the constant of proportionality for each set of similar polygons to find n.


8 cm
6 cm
5.5 cm
n

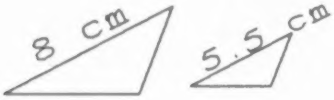


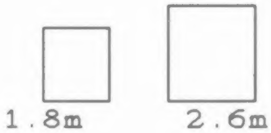

6mm
n
2mm
0.6mm

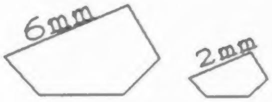
n = ______ n = ______ n = ______

In similar figures, the square of the ratio of corresponding segments is the ratio of the areas.

Determine the ratio of corresponding segments and the ratio of the areas of these similar figures:







$8k = 5.5$

$k = \frac{5.5}{8}$

$K_{area} = \frac{(5.5)^2}{(8)^2}$

Ratio of areas = $\frac{30.25}{64}$

$K_{area} = 0.4727$

$k =$ ______

$K_{area} =$ ______

Ratio of areas = ______

$K_{area} =$ ______

$k =$ ______

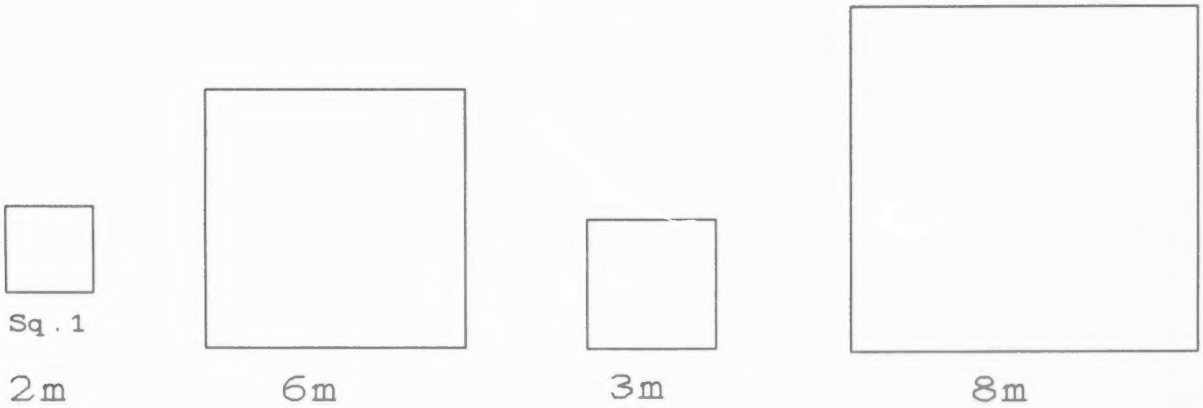
$K_{area} =$ ______

Ratio of areas = ______

$K_{area} =$ ______

The areas of similar figures are directly proportional to the squares of corresponding sides.

All squares are similar. Find (a) the linear constant of proportionality, (b) the area constant of proportionality, (c) the linear change (length change of one side), and (d) the area change, for the squares using Sq. 1 as the basis for each proportionality constant.



(a) k = 3	(a)_____	(a)_____
(b) K = 9	(b)_____	(b)_____
(c) $\Delta L = 4$	(c)_____	(c)_____
(d) $\Delta A = 32$	(d)_____	(d)_____

POST-LAB QUESTIONS

The expansion of certain metals is directly proportional to the rise in temperature. If wire made from Metal X has a proportionality constant (or heat expansion constant) of 1.05 when the temperature rises 1 degree, determine (a) the new length of the wire after temperature increases and (b) the expansion (ΔL = change in length) for the following lengths of wire:

(A) L_1 = 20 cm
Temp. +1 degree

(a) ________

(b) ΔL = ______

(B) L_2 = 500 m
Temp. +5 degrees

(a) ________

(b) ΔL = ______

(C) L_3 = 15 cm
Temp. +10 degrees

(a) ________

(b) ΔL = ______

The heat expansion constant is often given as a fraction per degree Celsius of temperature change, along with the range of degrees in which that constant is valid. The table gives some examples. The heat expansion constant is a fraction, which will give the expansion (the change of length) for wire made out of each particular metal.

aluminum	23.8×10^{-6}	20 - 100 °C
brass	19.3×10^{-6}	0 - 100 °C
copper	16.8×10^{-6}	25 - 100 °C
gold	14.3×10^{-6}	16 - 100 °C
steel	10.5×10^{-6}	0 - 100 °C

Find the expansion for each length of wire given the following:

Type of Metal	Length of Wire	Temperature Increase	Amount of Expansion	Resulting Wire Length
aluminum	30 cm	+1		
brass	8 m	+5		
copper	200 m	+10		
steel	50 cm	+5		

The constants for metal expansion can be used when computing the expansion of a sheet of metal (area) also. It turns out, that the constants (which are approximations) can be doubled to get the approximate area expansion constant. The fact that $2 \cdot \alpha = \beta$ is shown here:

α = heat expansion constant
β = area heat expansion constant
L = length
ΔT = increase in temperature

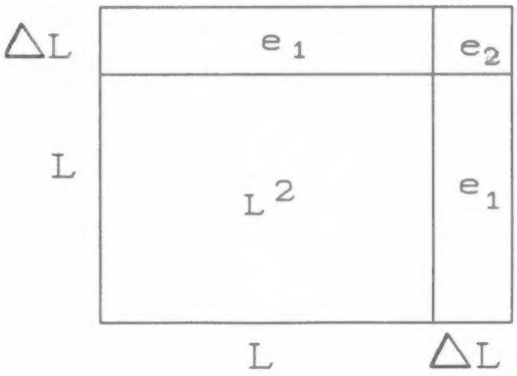
(1) $\Delta L = \alpha \cdot L \cdot \Delta T$ (constant x length x temperature increase)

(2) $\Delta A = \beta \cdot A \cdot \Delta T$ (area constant x ________ x ___________)

Solve for α and β in equations (1) and (2):

(3) $\alpha =$ (4) $\beta =$

Use the diagram and solve for ΔA (change in areas).



L^2 is the original area.

The sections e_1 are equal in size and with e_2 represent the increase (the expansion). The area of the sections $e_1 = L \cdot \Delta L$ The area of e_2 is $(\Delta L)^2$ The total area can be written two ways:

1. $(L + \Delta L)^2$ or

2. $L^2 + 2(L \cdot \Delta L) + (\Delta L)^2$

So the change in the area (or the expansion) is:

$$\Delta A = (L + \Delta L)^2 - L^2$$

$$\Delta = L^2 + 2(L \cdot \Delta L) + (\Delta L)^2 - L^2$$

(5) $\Delta A = 2(L \cdot \Delta L) + (\Delta L)^2$

In equation (4), β was solved for. Use equation (5) and substitute the expression representing ΔA into equation (4):
(Also let A be L^2)

$$\beta = \frac{\underline{\qquad} + \underline{\qquad}}{L^2 \cdot \Delta T} \qquad \beta = \frac{\underline{\qquad\qquad}}{L^2 \cdot \Delta T} + \frac{\underline{\qquad\qquad}}{L^2 \cdot \Delta T}$$

In equation (3), α was solved for. It is represented in the first fractional term. Substitute α into the equation. (Complete below)

$$2 \cdot \underline{\quad\quad} + \frac{\Delta L^2}{L \cdot \Delta T} = \beta$$

Note that the second term above is extremely small. Adding this amount to 2α does not alter 2α enough to consider it. Therefore: $\beta = 2\alpha$

Two times the linear coefficient (expansion constant) is the area coefficient. Following the same line of reasoning it could also be shown that the volume expansion coefficient is three times the linear coefficient. Use the coefficients (expansion constants) from the table to find the area or volume expansions for the following problems:

1. Find the change in area of a square sheet of aluminum 11.2 m on each side if the temperature increases from 22°C to 32°C.

2. A gold circular plate with a diameter of 15 cm is heated from 25°C to 45°C. What is the change in area? What is the area after the plate is heated to 45°C?

3. The volume of a brass spittoon is a disgusting 2 liters. The temperature in the saloon rises from 20°C to 30°C. How much does the volume increase?

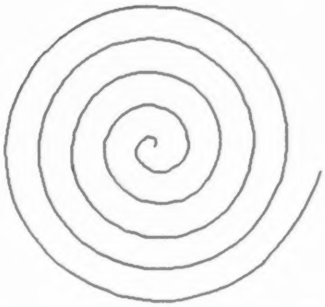
In a thermostat as the temperature rises a metal coil expands and triggers a switch which turns off the furnace. As the temperature decreases, the metal coil shrinks and switches the furnace on. A coil is used to add more length of material to a small physical space. The length of a spiral could be approximated by finding the circumferences of concentric circles.

4. In a spiral coil each loop approximates a circle. A spiral coil has 5 loops each with the following average diameters:

   0.80 cm, 1.10 cm, 1.40 cm, 1.70 cm, 2.00 cm

   Find the length of the spiral by computing each circumference and the sum.

5. In a spiral coil with 5 loops, the average diameter of the smallest loop is 0.80 cm. The average diameter of the largest loop is 2.00 cm. Therefore, the average diameter of the 5 loops is 1.60 cm. Find the length of the spiral by computing the average circumference and multiplying by the number of loops.



6. A brass spiral coil in a thermostat has six loops. The average of the loop diameters is 15 mm. Determine the change in length of the coil if the temperature is raised from 0°C to 30°C.

(Recall: $\Delta L = \alpha L \Delta T$)

7. An aluminum spiral coil has six loops. The average loop radius is 7.5 mm. Determine the change in length and the new length of the coil if the temperature drops from 20°C to -10°C.

PHYS-MA-TECH

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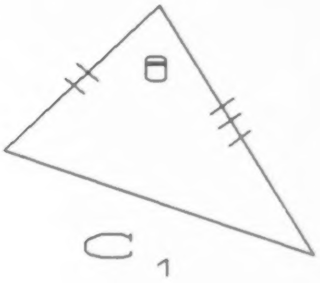
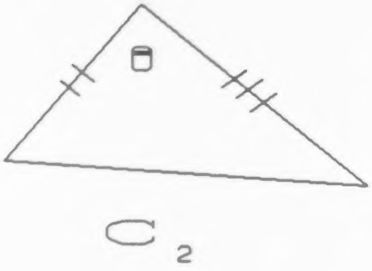
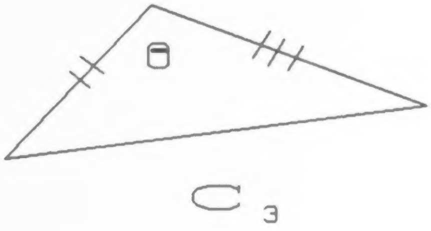
ELECTROMAGNETIC DOOR (HINGE THEOREM) MATHEMATICS WORKSHEET

For each triangle, use a protractor and ruler to find the measure of θ and the length of C.





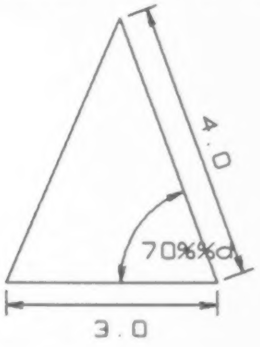


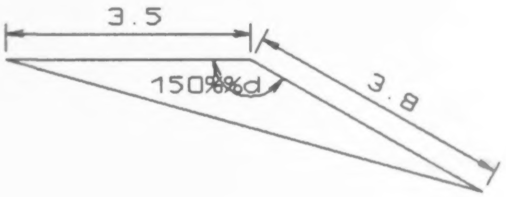
Verify that the segments marked as congruent DO have the same measure.

What relationship can be seen between the angles and the opposite sides?

Use the law of cosines to find the side opposite the given angle.

Law of cosines: $c^2 = a^2+b^2-2ab(\cos\angle c)$





Observing the relationship in the above problems between the changing angle and the side opposite, match the angle measure with the most appropriate length of opposite sides.

Correspond the included angle of congruent pairs of sides to the third side in the triangle. Choose your answers from the following list:

$\angle C_1 = 105°$ $d_1 =$ __________

$\angle C_2 = 32°$ $d_2 =$ __________

$\angle C_3 = 58°$ $d_3 =$ __________

Hinge Theorem: IF TWO SIDES OF ONE TRIANGLE ARE CONGRUENT TO TWO SIDES OF ANOTHER TRIANGLE BUT THE INCLUDED ANGLES ARE OF DIFFERENT MEASURES, THEN IN THE TRIANGLE WITH THE LARGER INCLUDED ANGLE, THE SIDE OPPOSITE IS LARGER.

In a circle, four distinct radii are drawn, no two of which form a diameter. The angles (clockwise) between the radii are 90°, 120°, 80°, and 60°. The chords formed by the ends of the radii are (clockwise) $\underline{AB}$, $\underline{BC}$, $\underline{CD}$, and $\underline{DA}$. List the chords in order from smallest to largest.

In an isosceles right triangle (ΔABC), the right angle ($\angle B$) is divided in the ratio of 4:5 by $\underline{BX}$ such that $\angle ABX < \angle CBX$.

(a) Draw a diagram of this triangle with the angle divided.

(b) Complete the following, using <, >, or =.

BA CB $\qquad$ $\angle BXA$ $\angle CXB$
AX XC $\qquad$ $\angle BAX$ $\angle BCX$

(c) If one leg of the triangle is 10 cm, what is the length of AX and XC?

(d) What are the measures of:

$\angle ABX =$ $\qquad$ $\angle BXA =$ $\qquad$ $\angle XAB =$

$\angle BCX =$ $\qquad$ $\angle CXB =$ $\qquad$ $\angle CBX =$

The converse of the Hinge Theorem is also true.

Converse Hinge Theorem: IF TWO SIDES OF ONE TRIANGLE ARE CONGRUENT TO TWO SIDES OF ANOTHER TRIANGLE BUT THE THIRD SIDES ARE OF DIFFERENT MEASURES, THEN IN THE TRIANGLE WITH THE LARGER SIDE, THE ANGLE OPPOSITE IS LARGER.

A quadrilateral is inscribed in a circle. From the center of the circle radii are drawn to the vertices of the quadrilateral. The lengths of the sides of the quadrilateral are:

$$AB = 7, \quad BC = 6, \quad CD = 9, \quad \text{and} \quad DA = 2$$

The central angles opposite these sides are numbered $\angle 1$, $\angle 2$, $\angle 3$ and $\angle 4$ consecutively. List the angles in order, smallest to largest.

$\triangle ABC$ is a non-isosceles right triangle with median $\underline{BX}$ drawn from the right angle. $\underline{AB}$ is the shorter leg.

(a) Draw a diagram of the triangle with the median, labeling all points.

(b) Complete the following using <, >, or =

$\angle CXB \quad \angle AXB \qquad CX \quad AX$

$\angle XBC \quad \angle XBA \qquad AB \quad BC$

ACTIVITY 5: SMOKE ALARM

TECHNOLOGICAL FRAMEWORK: A combination of radiation and electronics is used in the makeup of a sensor to detect smoke and/or other airborne molecules in homes, businesses, and industries.

PURPOSE: To understand how an ionization chamber detector works. Measure radiation rate using photographic film of alpha counter.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--ionization, radiation, direct current circuits

Mathematics--area, distance, proportions

Technology--fire safety, scaling with CAD, drafting scales, Piezoelectric effect.

PRE-REQUISITES: Schematic drawing, circuits, atomic structure

Radioactive elements, alpha decay, beta decay

MATERIALS, EQUIPMENT, APPARATUS: Ionization chamber smoke detectors, photographic film or alpha counter, darkroom facilities, butane lighters (Aim'n-Flame), wood matches, hair dryer, chalk erasers, candles

TIME FRAME:	For the laboratory activity, 1 class period
TEACHING STRATEGIES:	As a whole class, students are taught about radiation and ionization. Include discussion on circuitry necessary to amplify the small current, and activating the Piezo horn. Small groups (2 to 3 students in a group) will identify components and use either photographic film or an alpha counter to measure radiation. Included in the discussion are the positive uses of radiation such as: power production, material testing, medical applications, scientific research. Show video "Plan to Get Out Alive" (produced by BRK Electronics and McDonald's). Use worksheets to prepare a residential fire safety plan.
TEACHING METHODOLOGY:	Discuss the structure of the atom and natural radioactive particles. Students working in small groups (2 or 3 per group) will open up an ionization chamber smoke detector and identify the components, measure potential difference at the voltage divider, and use an alpha counter or film to detect radiation. Information: The test button on the smoke detector tests all functions of the smoke detector (battery, horn, and ion chamber), not just the battery.
FURTHER FIELDS OF INVESTIGATION:	Apartments, houses, and industrial uses. Fire safety.

BASIC INFORMATION REGARDING SMOKE DETECTORS

What Smoke Detectors Can Do

Smoke detectors are designed to sense smoke that comes into the sensing chamber. They do not sense gas, heat or flame. Smoke detectors are designed to give early warning of developing fires at a reasonable cost. Smoke detectors monitor the air. When they sense smoke, they sound their built-in alarm horn. They can provide precious time for you and your family to escape before a fire spreads. Such early warning is only possible, however, if the detector is located, installed, and maintained as described in its User's Manual.

There are two basic types of residential smoke detectors used today, ionization detectors and photoelectric detectors. Both detectors have sensing chambers which operate in different ways to sense products of combustion given off by developing fires.

How Ionization Chamber Detectors Work

A basic ionization chamber consists of two electrically charged **plates** and an Americium 241 source for ionizing the air between the plates (see Diagram 1). The source emits alpha particles which collide with air molecules inside the chamber and dislodge their electrons. As molecules lose electrons, they become **positively charged ions.** An equal number of positive and negative ions are created. The positively charged ions are attracted to the negatively charged electrical plate (see Diagram 2) and the negatively charged ions are attracted to the positively charged plate. A minute ionization current is created which can be measured by electronic circuitry connected to the electrical plates.

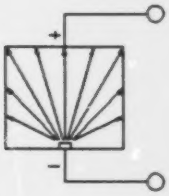


Diagram 1

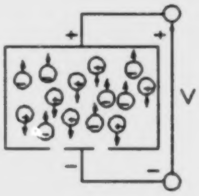


Diagram 2

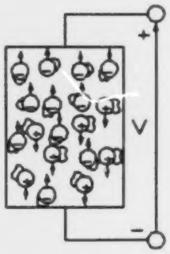


Diagram 3

As **particles of combustion** enter an ionization chamber (see Diagram 3), ionized air molecules collide and combine with them. Some particles become positively charged and some become negatively charged. As these ionized particles continue to combine with other ions, some lose their charge as they combine with oppositely charged ions. A reduction in the number of ionized particles in the chamber occurs. The reduction in the ionized particles results in a decrease in chamber current which is sensed by electronic circuitry monitoring the chamber.

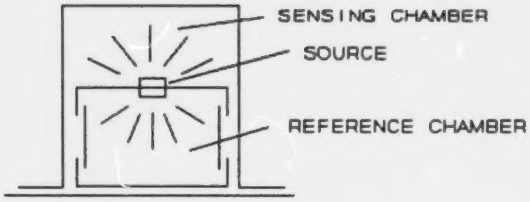


Diagram 4

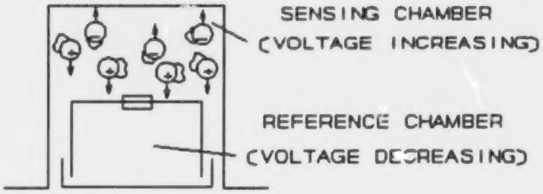


Diagram 5

When fire researchers discovered the sensing capabilities of ionization chambers, they also learned that changes in humidity and atmospheric pressure could affect chamber current and create an effect similar to particles of combustion entering the chamber. To compensate for the possible effect of humidity and pressure changes, these researchers developed the **dual ionization chamber** which has become commonplace in the smoke detector market. A dual chamber sensor utilizes two ionization chambers (see Diagram 4), one a **sensing chamber** exposed to outside air and the other a **reference**

chamber effectively shielded from the outside air. The sensing chamber is affected by particulate matter, humidity, and atmospheric pressure humidity and atmospheric pressure because its tiny openings effectively block the entry of larger particulate matter such as smoke or because it is designed to be insensitive to smoke particles.

Electronic circuitry monitors both chambers and compares their current and voltage outputs. If humidity or pressure changes, both chambers' outputs are affected simultaneously. If particles of combustion enter the sensing chamber (see Diagram 5), however, its voltage will increase while the voltage of the reference chamber will decrease. The resulting voltage imbalance is detected by the electronic circuitry.

Some important design problems which must be considered in ionization detectors are: ensuring that the electrical circuitry which monitors the ionization chamber has lower leakage current than the already minute ionization current; ensuring that the sensing chamber is relatively immune to other environmental effects such as electrostatic fields and high air velocities while being relatively transparent to the entry of products of combusion. All of BRK ionization detectors have been carefully optimized for these important parameters.

BRK ELECTRONICS
A DIVISION OF PITTWAY CORPORATION
780 McClure Road Aurora, Illinois 60504-2495
Area Code (708) 851-7330 Telex: 4330938BRK ARA

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C368 5/89

PROCEDURE:

Safety measure: Half fill a bucket of water before starting test procedures. Do not allow any flames to come into contact with the smoke detector.

Step 1: Test operation of smoke alarm and record results, using butane lighter (cigarette lighter), wood match burning, wood match after flame is blown out, hot air (from hair dryer), chalk dust (by clapping two erasers together), lighted candle, candle after flame is blown out, burning upholstery material (discard into bucket of water), blow warm moist air (from your lungs).

Step 2: Measure the potential difference between the upper and lower plate of the ionization chamber. (See Diagram 6; measure potential difference between pin 15 and ground.)

Step 3: Measure the potential difference between the upper and lower plate of the ionization chamber with the test button activated. (See Diagram 6; measure potential difference between pin 15 and ground.)

Step 4: Measure, with battery removed, the resistance of each of the resistors on the circuit board. Determine if the resistors' values are within tolerance limits.

Step 5: Open the smoke alarm and take off the top to the radioactive source.

Step 6: Measure the radiation of the radioactive source using an alpha counter. (Note: Local industries or businesses which handle nuclear decay substances might provide a person to speak and demonstrate an alpha counter, e.g., BRK Electronics, Aurora, IL).

Step 6 (alternate): If using photographic film to measures radiation, an exposure time of several days is required.

Step 7: Complete the worksheet for Ionization Chamber Smoke Detector.

View video "Plan to Get Out Alive."

Complete worksheet(s) on fire safety.

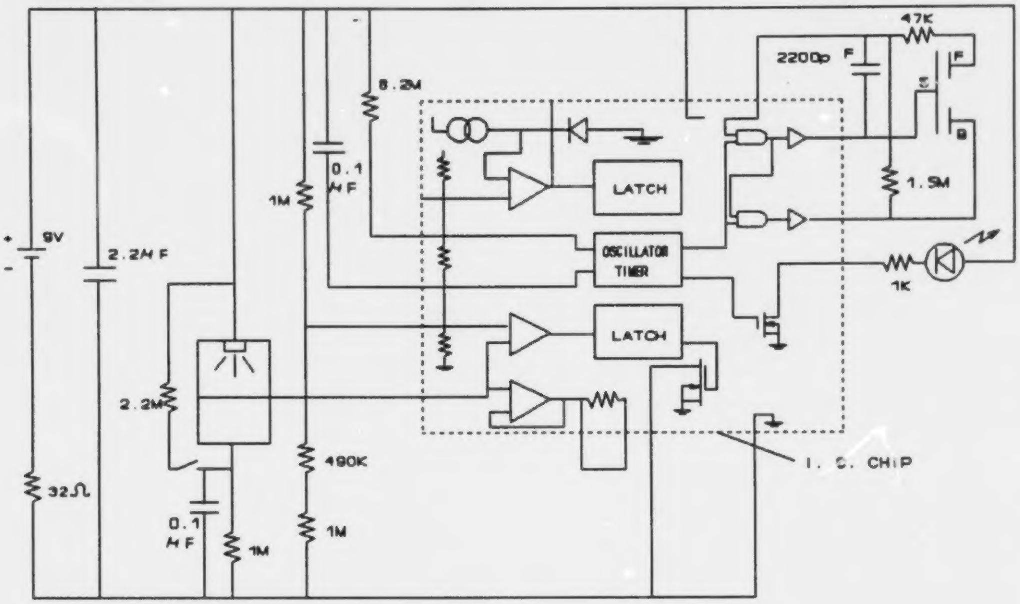

+
-
9V
2.2μF
32Ω
2.2M
0.1 μF
1M
1M
0.1 μF
8.2M
490K
1M
LATCH
OSCILLATOR TIMER
LATCH
2200p F
47K
F
S
B
1.5M
1K
I. C. CHIP

Diagram 6

ANTICIPATED PROBLEMS:

When creating smoke and heat in the classroom, do not burn any synthetic materials (also, ramie, a natural fiber, is extremely flammable).

METHODS OF EVALUATION:

Completion of worksheet.
Follow-up discussion.

FOLLOW-UP ACTIVITIES:

Investigate the kind of smoke detector system(s) used in your school.

On every industrial visit, ask to be shown the smoke detection system(s) used.

Visit a company that makes smoke detectors and sensor systems. Students can be assigned to draw a sketch of their home floor plan, which can be entered into a computer. With the use of CAD, a personal fire safety plan can be developed. Visit medical facilities, electrical generation plant (nuclear), industries which use radiation in testing processes and materials, etc.

REFERENCES, RESOURCES, VENDORS:

Hardware store

BRK Electronics
780 McClure Rd.
Aurora, IL 60504-2495
Area Code (708) - 851-7330
Telex: 4330938 BRK ARA

POST-LAB QUESTIONS: SMOKE ALARM WORKSHEET

Complete the chart:

Test Source	Result	Test Source	Result
Butane Lighter		Lighted Candle	
Match Flame		Candle Smoke	
Match Smoke		Burning Upholstery	
Hot Air		Moist Warm Air	
Chalk Dust			

Resistance Table

Resistor	Measured Value	Within Tolerance	
		Yes	No
33			
2.2 m			
1 m (A)			
1 m (B)			
490 k			
1 m (C)			
47 k			
1.5 m			
1 k			

1. Which of the following cause a smoke detector to activate?
   - (a) flame
   - (b) heat
   - (c) particles
   - (d) gas

2. What is the purpose of the radioactive element?
   - (a) to ionize air molecules
   - (b) to recharge the battery
   - (c) to generate heat
   - (d) to emit beta particles

3. What is an ion?__________________________________

4. What is an alpha particle?__________________________

PHYS-MA-TECH

AN INTEGRATED PARTNERSHIP

SMOKE DETECTOR MATHEMATICS WORKSHEET

Simplify and express answer using scientific notation.

Suggested steps to simplify:

(a) Express each number as a whole number and a power of ten.

(b) Write two separate fractions, one with the whole numbers and the other with the powers of ten.

(c) Simplify each fraction.

(d) Write the resulting whole number fraction as a decimal number ($1 \leq n < 10$) and the power of ten.

Example:

$$\frac{(1{,}500{,}000 x 10^{-6})(1{,}800 x 10^{4})(140{,}000 x 10^{-2})}{(2700 x 10^{-3})(80{,}000 x 10^{2})(350 x 10^{6})}$$

$$\frac{15 \cdot 18 \cdot 14}{27 \cdot 35 \cdot 8} \cdot \frac{10^5 x 10^{-6} x 10^2 x 10^4 x 10^4 x 10^{-2}}{10^2 x 10^{-3} x 10^4 x 10^2 x 10 x 10^6}$$

$$\frac{1}{2} \cdot \frac{10^7}{10^{12}}$$

$$0.5 x 10^{-5}$$

$$5.0 x 10^{-6}$$

Try These:

1. $\dfrac{(3{,}500{,}000)(2400 x 10^{7})}{(280{,}000 x 10^{-2})(150 x 10^{8})}$

2. $\dfrac{(12{,}000{,}000 x 10^{-3})(1{,}400 x 10^{6})}{(2{,}800{,}000 x 10^{-4})(800 x 10^{9})}$

"HALF-LIFE" is the time required for half of a substance to decay.

3. What percent of the substance remains after one half-life?

4. What percent of the substance remains after two half-lives?

5. Complete the table to show what percent is left after the number of half-lives.

Percent Remaining	After N Half-Lives
	N = 2
	N = 3
	N = 4
	N = 5

6. A substance has a volume of 200 cubic inches. Find the volume of the third half-life.

$$\frac{1}{2}\left(\frac{1}{2}\left(\frac{1}{2}(200)\right)\right)$$

$$\frac{1}{8}(200)$$

$$2^{-3}(200)$$

Simplify:

7. $2^{-5}(50{,}000)$

8. $2^{-3}(3.0 \times 10^{5})$

9. $2^{-7}(6.25 \times 10^{9})$

10. (a) What half-life is represented in (7)?

(b) What percent of the substance would be remaining?

11. (a) What half-life is represented in (8)?

(b) What percent of the substance would be remaining?

12. If the head on a glass of root beer has a half life of 3 minutes,

    (a) what percent of the foam remains after 9 minutes?

    (b) if the head was 2.8 cm when the root beer was poured, what is its height after 12 minutes?

13. The half-life of radium-226 is 1620 years. For all practical purposes, after 7 half-lives all of the atoms (99%) have decayed into simpler atoms. How many years would this take?

14. Polonium-214 has a half-life of 1.55×10^{-4} seconds.

    (a) How many atoms are left after 2 half-lives if you start with 2.56×10^{12} atoms?

    (b) How long will it take for the polonium to totally decay (99%) for practical purposes?

ACTIVITY 6:	PROGRAMMABLE HOME THERMOSTAT
TECHNOLOGICAL FRAMEWORK:	Installation of programmable heating/cooling for conservation of energy. (Save money)
PURPOSE:	To install and program a thermostat. To graph warming and cooling temperatures as a function of time. To determine the effects of insulation. To determine the relationship between Fahrenheit and Celsius scales.
ILLINOIS LEARNER OUTCOMES:	As a result of their schooling, students will have a working knowledge of: •The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society. •The principles of scientific research and their application in simple research projects. •The processes, techniques, methods, equipment, and available technology of science.
CONCEPTS:	Physics--temperature scales, thermal conductivity, heat and kinetic theory Mathematics--proportions, linear relationships to convert temperature scales Technology--insulating, climate control
PRE-REQUISITES:	None

MATERIALS, EQUIPMENT, APPARATUS: A programmable thermostat (Hunter Model 42204 or similar product), 24-V/110-V transformer, bell wire, 24-V bulb and base (or 24-V pilot light), junction box, 110-V single pole switch, ceramic disk heater (or similar heating device), 1/4" peg board 8-cubic foot enclosure, fiberglass insulated 8-cubic foot enclosure, computer interfaced temperature probe.

TIME FRAME: 1 class period to teach concepts, 1 class period to install and program thermostat, a class period to collect and interpret data.

TEACHING STRATEGIES: Mathematics teacher--temperature scale conversion (as a linear relationship), graphing and proportions (change in temperature), assist in laboratory activity.

Physics teacher--thermometers, temperature scales (including Kelvin), discuss kinetic theory, assist in laboratory activity.

Technology teacher--construction of enclosures, instruction on installation of thermostats, assist in laboratory activity.

Assembly and installation takes place in the Technology lab. Testing and interpretation take place in the Technology lab or classroom (enclosures are mobile).

Activity One: Students will work in pairs installing the programming thermostats.

Activity Two:

Option 1. Students collect data from Super Champ temperature in teams (pairs).

Option 2. Data are collected as a class. Students will graph data individually.

TEACHING METHODOLOGY:

Activity One: Students work in pairs for installation and programming of thermostat on mock-up walls.

Period 1: Cover temperature conversion concepts, kinetic theory.

Period 2: Students will be provided with a "wall" with three wires coming from it (as if they had just removed a home thermostat). Using the instruction manual and student worksheet, students will install and program the thermostat as per directions on worksheet. This will allow for collecting data during the class on the next consecutive day.

Period 3: Students will verify programming of thermostat.

Activity Two: An 8-cubic-foot peg board enclosure (2 x 2 x 2) with a ceramic heater will be the "room" where the temperature data are collected for 5 minutes. The heater will be turned off and data collected for a 10-minute cooling period. Then the enclosure will be insulated with 3 1/2" fiberglass batts and temperature data will be collected again.

Students will use Super Champ (or other computer-based) temperature probe to collect data from the heating and cooling of the two enclosures. Students will sketch two heating graphs of temperature as a function of time on one set of axes and two cooling graphs of temperature as a function of time.

Activity Three: Students will work in small groups and complete graphs to convert temperature scales.

FURTHER FIELDS OF INVESTIGATION:

Home, business, and industrial environment control.

PROCEDURE:

Activity One

Step 1: Read installation instructions from thermostat manual and install thermostat as directed.

Step 2: Read programming directions from thermostat manual and program as indicated on Programmable Thermostat Worksheet.

Step 3: Complete the Programmable Thermostat Worksheet.

Step 4: (Next day) Observe the "pilot" light and determine if your programming is correct.

Activity Two

Step 1: Collect data on non-insulated enclosure from Super Champ (or other computer-based) temperature probes for heating periods: 5 minutes on, 10 minutes off.

Step 2: Place insulated enclosure over the peg board enclosure and collect data for the same time periods.

Step 3: On one graph, sketch heating temperature as a function of time for non-insulated and insulated enclosures.

Step 4: On a second graph, sketch cooling temperature as a function of time for both enclosures.

Activity Three

Temperature Scale Conversions Worksheet (attached)

ANTICIPATED PROBLEMS:

Thermostat should be programmed in such a way that it will run the next class day. You do not want to start this activity on Friday, unless you restructure your initial time on the thermostat.

METHODS OF EVALUATION:	Successful programming of thermostat is observed by students and teachers. Worksheet is completed and reviewed.
FOLLOW-UP ACTIVITIES:	In industrial visits, ask about environment control systems. Environment survey of student homes. Presentation by home energy conservationist (insulation, caulking, thermal windows, etc.). Suggestions for change: environmental control, heat transfer, effects of insulation. Plot temperature as a function of time and do temperature scales. Determine R-factor of insulation.
REFERENCES, RESOURCES, VENDORS:	Hardware store Energy research companies (e.g., Potential Energy, Inc., Chicago, IL) Local gas company (e.g., N.I. Gas)

PROGRAMMABLE HOME THERMOSTAT WORKSHEET

This is a worksheet that corresponds to the personal program schedule in the thermostat's instruction booklet. Use the instruction booklet (that comes with the thermostat that was purchased for this activity) to complete this worksheet. This activity will take two days. The first day you will program the thermostat. The second day you will test your program. In order to test your program for weekdays and weekends, you will need to set your thermostat for an initial time of 11:00 p.m. Thursday.

Beginning Program Date			
WINTER PROGRAM			
WEEKDAYS	TIME	AM/PM	TEMP.
PROGRAM 1	11:00	PM	
PROGRAM 2	11:15	PM	
PROGRAM 3	11:30	PM	
PROGRAM 4	11:45	PM	
WEEKEND			
PROGRAM 1	12:00	AM	
PROGRAM 2	12:15	AM	

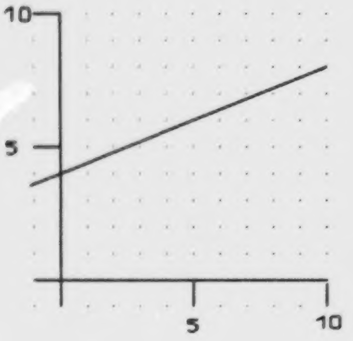
Beginning Program Date			
SUMMER PROGRAM			
WEEKDAYS	TIME	AM/PM	TEMP.
PROGRAM 1			
PROGRAM 2			
PROGRAM 3			
PROGRAM 4			
WEEKEND			
PROGRAM 1			
PROGRAM 2			

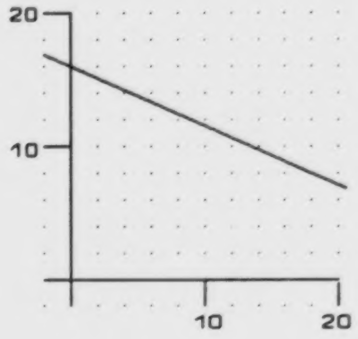
Your goal is to program the thermostat in such a manner that the first 15 min. time period causes the "furnace" light to come on. The second time period causes the light to turn off; the third period the light is on, and the fourth it is off. The weekend program should light the "furnace" light and then turn it off. Complete the Summer Program portion of this sheet to meet the needs of a typical household. You will not actually program the thermostat for the summer cycle, as this thermostat will not hold both schedules simultaneously. We will look for workable programming on your chart. Use realistic times for the summer program.

PLEASE TURN IN THIS WORKSHEET AFTER YOU HAVE INSTALLED YOUR THERMOSTAT AND COMPLETED YOUR PROGRAMMING. TURN IN THIS WORKSHEET BEFORE TESTING YOUR SET-UP.

SLOPE INTERCEPT FUNCTIONS: MATHEMATICS WORKSHEET 1

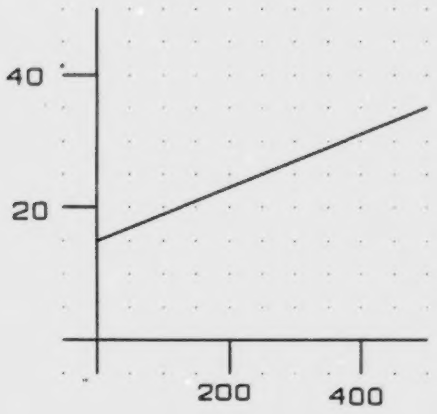
Complete this worksheet prior to Temperature Scale Conversions: Mathematics Worksheet 2. Find the slope, y intercept, equation, and values as indicated.

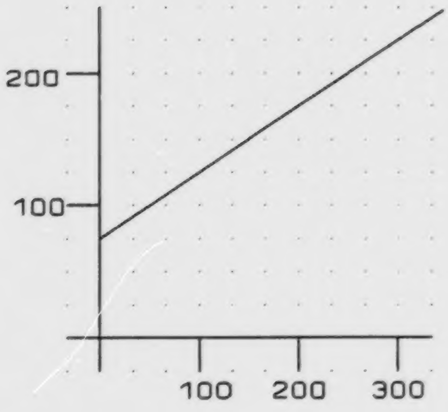




slope = _____
y-intercept = _____
f(x) = _____
x-intercept = _____

slope = _____
y-intercept = _____
f(x) = _____
x-intercept = _____





slope = _____ y-int = _____
f(x) = _______________
for x = 300 find f(x) ________

slope = _____ y-int = _____
f(x) = _______________
for x = 500 and x = 0 find f(x)
f(500) ________ f(0) = ________

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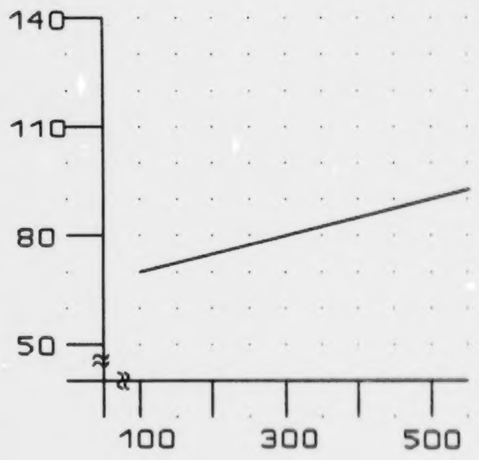
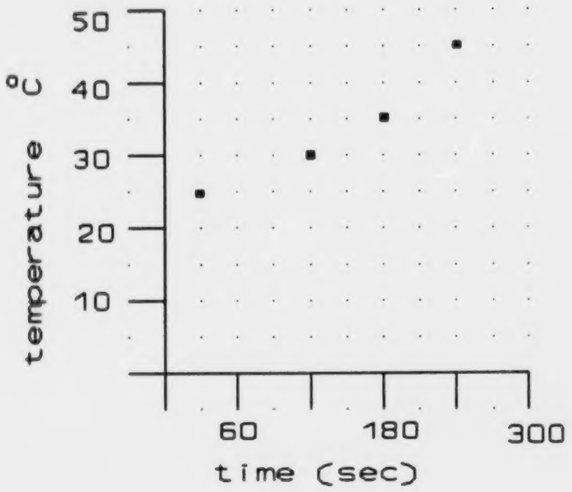
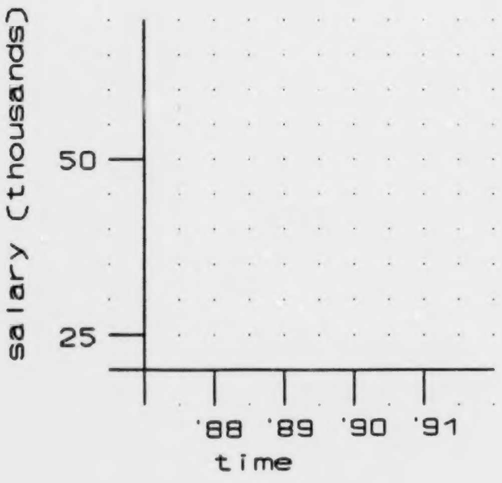
Activity 6
Programmable Home Thermostat

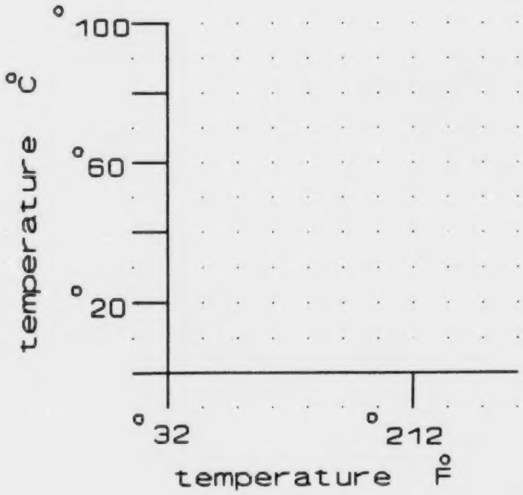




f(100) = ______
f(300) = ______
f(400) = ______
f(x) = ______

temperature is graphed as
a function of time.
f(120) = _____ f(240) = _____
f(30) = _____ f(140) = _____





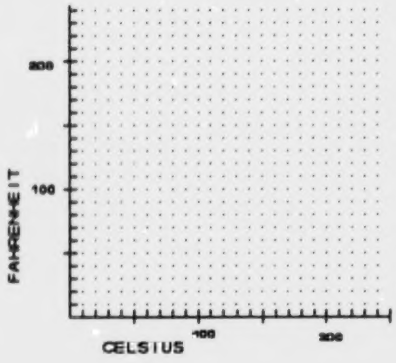
1988 - $25,000 1989 - $32,000
1990 - $47,000 1991 - $55,000
f('92) = _______

freezing pt. ___°F ___°C
boiling pt. ___°F ___°C
f(x) = _____

PHYS-MA-TECH

AN INTEGRATED PARTNERSHIP

TEMPERATURE SCALE CONVERSIONS: MATHEMATICS WORKSHEET 2



1. Graph Fahrenheit versus Celsius using freezing point and boiling point to determine the linear relationship.

2. What is the vertical intercept? ___________

3. What is the slope? __________

4. Write the linear equation (y = mx + b) _____

5. If C = 50, then F = __________

6. When the Celsius scale reads 10°, the Fahrenheit reads _______

7. 15°C = _____F 8. -5°C = _____F 9. 25°C = _____F

10. To the nearest degree, 34°C = _____F

11. Rewrite the equation in (4.), solving for C = __________

12. If F = 86, then X = _____

To the nearest degree, find:

13. 12°F = _____C 14. -18°F = _____C 15. 60°F = _____C

0° Kelvin = -273° Celsius 273° Kelvin = 0° Celsius

16. On a piece of graph paper, graph Kelvin versus Celsius.

17. What is the vertical intercept?__________

18. What is the slope?__________

19. Write the linear equation (y = mx + b)__________

20. Solve for C. C = __________

21. 200°K = _____C 22. 50°C = _____K 23. 350°K = _____C

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Aurora West High School
Activity 6
Programmable Home Thermostat

24. 100°F = _____F   25. 300°K = _____K   26. 0°F = _____K

27. Rewrite the equations (4.), (11.), and (19.), replacing x's and y's with C (Celsius), F (Fahrenheit), and K (Kelvin).
F = ___________   C = ___________   K = ___________

THERMOMETRY: MATHEMATICS WORKSHEET 3

Use the equations developed on the TEMPERATURE SCALE CONVERSION worksheet to convert the following specific temperatures.

(Note: There are two *'ed conversions which are changes in temperature, not specific temperatures.)

68°F = ______ °C

*18F° = ______ C°

*40C° = ______ F°

0°K = ______ °F

70°F = ______ °C

250°F = ______ °C

125°C = ______ °F

10°F = ______ °C

-5°C = ______ °F

-50°C = ______ °K

120°F = ______ °C

17°C = ______ °F

5°C = ______ °F

20°F = ______ °C

-50°F = ______ °C

55°F = ______ °K

77°K = ______ °F

98.6°F = ______ °C

0°K = ______ °C

150°F = ______ °K

PHYS·MA·TECH

AN INTEGRATED PARTNERSHIP

LIST OF ACTIVITIES

CURIE HIGH SCHOOL

		Inclusive Page Nos.
Activity 1	Xerography	579-591
Activity 2	Bar Hopping: Bar Coding	592-621
Activity 3	Cryogenetics	622-636
Activity 4	Centrifuge	637-651
Activity 5	Cold Cuts: Commercial Ice Machines .	652-673
Activity 6	AM/FM Signals	674-706

ACTIVITY 1: XEROGRAPHY

TECHNOLOGICAL FRAMEWORK: Students are to discover the origins of xerography through the use of electrostastics. They will re-trace (to a certain extent) the process of making a crude Xerox copy.

PURPOSE: The student will be able to explain the process of xerography.

The student will explain the use of static electricity to transfer images

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--Electrostatics: (1) electrical charges, (2) Coulomb's Electrical Force Law: $F = Q1*Q2*K/r^2$, and (3) electrostatic induction

Mathematics--Inverse Square Law

Technology Skill--Assembling materials and processes

PRE-REQUISITES: Know positive and negative charges; know how to induce charges on materials such as glass, plastic, paper, metals, etc.; know units for charges, and attraction and repulsion.

MATERIALS, EQUIPMENT, APPARATUS:	Aluminum sheet (1 mm) Mylar Copier toner Aluminum and styrofoam Fur and silk cloth Glass and plastic rods Van Der Graaf generator Plain meter probes Wires Alligator clips
TIME FRAME:	Two 40-minute class periods
TEACHING STRATEGIES:	Instruction by construction and imitation of an older process (one that is similar).
TEACHING METHODOLOGY:	Inquiry into the methods of xerography, and actually instructing how to assemble equipment to make a crude Xerox copy.
FURTHER FIELDS OF INVESTIGATION:	Technical representative from Xerox will demonstrate the technology involved in a modern Xerox machine.

PROCEDURE:

In the early 1930s, a patent attorney named Chester Carlson developed a new way to make copies. He found the photographic process to be very time consuming and costly due to the usage of chemicals. His original setup and process have since been refined and upgraded into a multi-million-dollar business.

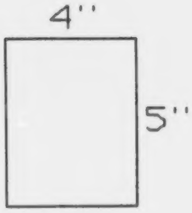
The new process uses an aluminum base, coated with a thin layer of aluminum oxide which in turn is coated with a layer of selenium. Charges can then be put onto this plate.

This is the function of selenium: Se is a photoconductive element. As light strikes the selenium, the electrons reach an excited state. The electrons in the excited state will combine and conduct the positive charges away from the plate. The (+) charges are then transferred to the aluminum base to be neutralized. The aluminum oxide will act as an insulator to slow down the discharge.

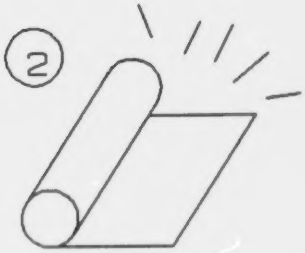
In this lab, the students will be able to make a crude Xerox copy of an image that they will draw onto a mylar-coated aluminum base plate. They will draw not with pen or pencil, but with a probe which is connected to a Van Der Graaf generator. The image will be made with the addition of toner to the plate and the image will be transferred to a sheet of paper. It is recommended that to save the copy, hair spray should be applied to it. The spray fixes the image onto the paper and should not be so easily smudged.

The early method that Carlson used involved selenium plates which were hard to locate and purchase; therefore, the mylar and aluminum plates were used. These gave good results, were less expensive, and easier to obtain. Students should realize that the charges that made Xerox copies are identical to charges that shocked them as they walked across the carpet and touched a door knob on a winter's day (static electricity).

Materials needed:

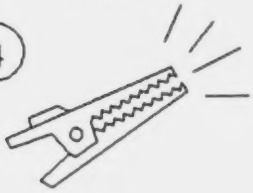
①


ALUMINUM PLATE

②

MYLAR SHEET

③

INSULATED WIRE

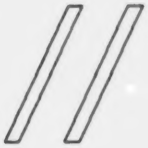
④

ALLIGATOR CLIPS

⑤

COPIER TONER

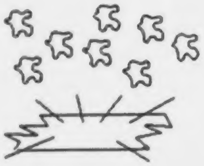
⑥

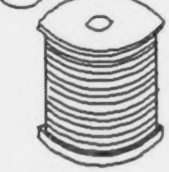
PAPER

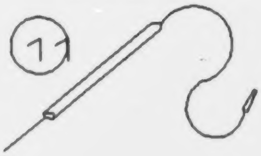
⑦

GLASS & PLASTIC RODS

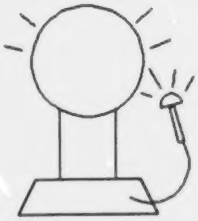
⑧

FUR & SILK CLOTHS

⑨

AL. FOIL & STYRO-FOAM BITS

⑩

THREAD

⑪

PROBE

⑫

VAN DER GRAAF

To test, identify the charges

Setup:

1. Cut mylar into 4-3/4" x 3-3/4" rectangles and tape sides to aluminum plate (see Figure C-1-1, "Attachment of Plates").
2. Plug in Van Der Graaf and gently go over the mylar coating (touch but try not to rip the mylar) with the grounding rod of the Van Der Graaf (see Figure C-1-2, "Van Der Graaf Application").
3. Wrap the styrofoam bits with aluminum foil into small little balls. (Tie threads to the styrofoam bits first.) Make two of these. (Make sure hands are dry.)
4. Charge the plastic rod with the silk cloth by rubbing it quickly and touch these to the aluminum styrofoam balls until the ball repels away form the stick. (One person holds the ball on a thread; the other touches it with the rod.) The ball acquires the same charge as the rod (see Figure C-1-3, "Charging").
5. Now hold the styrofoam ball up to the mylar plate (see Figure C-1-4, "Ball and Plate") and see if they attract or repel (write down below).

   Reaction:______________________________________
6. Repeat steps 4 and 5 with the fur and glass rod. Then record the reaction.

   Reaction:______________________________________

Question: What charge is on the metal plate and the grounding rod of the Van Der Graaf?

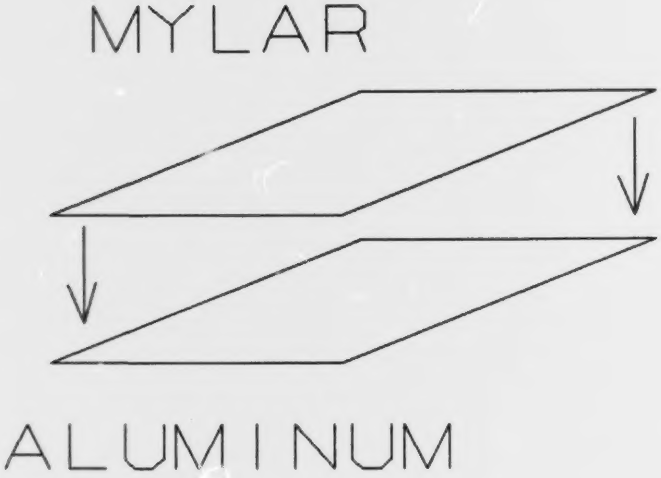

MYLAR
ALUMINUM

Figure C-1-1

Attachment of Plates

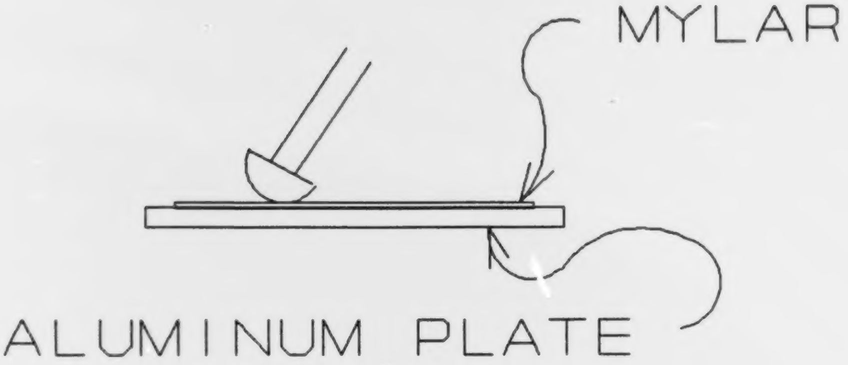

MYLAR
ALUMINUM PLATE

Figure C-1-2

Van Der Graaf Application

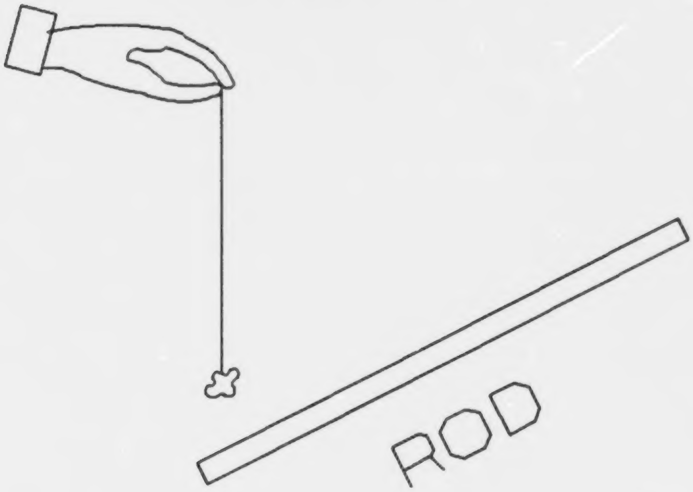


Figure C-1-3

Charging

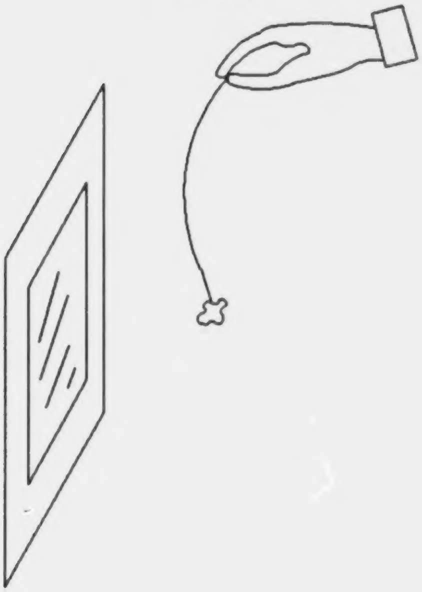


Figure C-1-4

Ball and Plate

To make a crude Xerox

Procedure:

1. Wipe the mylar plate with a damp cloth to get rid of existing charges.

2. Remove the grounding rod from the Van Der Graaf using alligator clip and insulated wires (see Figure C-1-5, "Alligator Clip").

3. Make sure mylar is dry or it will not work properly.

4. Slowly trace an image onto the mylar but try not to scratch it. (Can use a template or do free hand) See Figure C-1-6, "Tracing the Image").

5. Sprinkle toner onto the plate and let extra slide off. It is best to use toner with a (+) carrier. It would give a better picture. (It would be less messy.)

6. Shake off excess after the image forms.

7. Put a blank piece of paper on top of the mylar/aluminum plate with image. Lightly rub the paper to get image onto the paper.

8. To fix image on the paper, put paper with image under heat lamp or use hair spray to hold image.

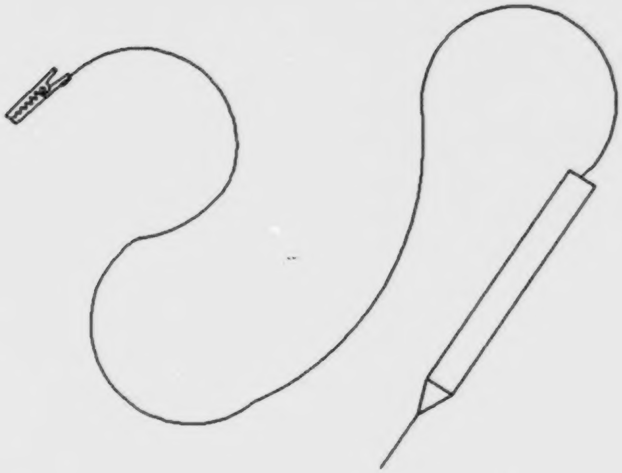


Figure C-1-5

Alligator Clip

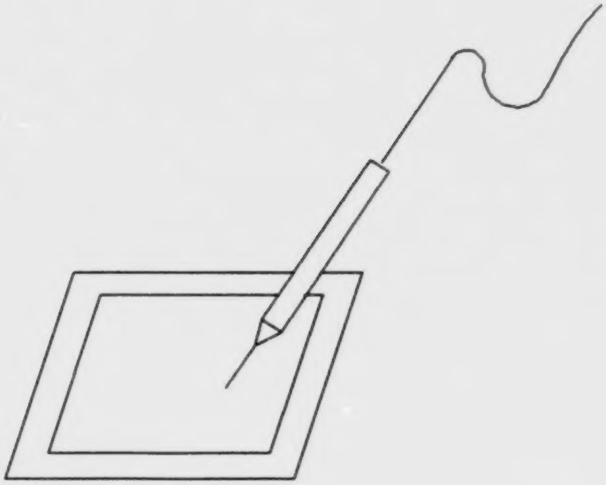


Figure C-1-6

Tracing the Image

ANTICIPATED PROBLEMS:	This lab will produce better results if conducted during winter months when relative humidity is low.
METHODS OF EVALUATION:	Each student will set up the lab and produce a copy of an image. Instructors will check for completion of worksheet.
FOLLOW-UP ACTIVITIES:	Technical representative Xerox will demonstrate the technology involved in a modern Xerox machine.
REFERENCES, RESOURCES, VENDORS:	Xerox Corporation Xerox Technigraphic Product 317 Main Street East Rochester, NY 14445 (716) 383-7178 Contact: Bob Gunlach, Dick Bergen, Lloyd F. Bean
	Xerox Corporation 55 W. Monroe St. Chicago, IL 60603 (312) 454-2652 Contact: James Knight, Field Service Manager
	Arts supply shop for mylar Sheet metal shop for aluminum sheets
	How Things Work. (n.d.). Geneva, Switzerland: Bibliographisches Institute and Simon & Schuster, Inc., American Ed., Edito Service S.A.
	The Illustrated Encyclopedia of Invention (Vol. 22). (1984). Westport, CT: H. S. Stuttman, Inc.
	Raymond A. Serway. (1986). Physics for Scientists and Engineers (2nd ed.). Orlando, FL: Holt, Rinehart, & Winston.

POST-LAB QUESTIONS: XEROGRAPHY

1. Name the different types of charges.

2. State the laws for the different charges.

3. What is the charge on a proton? ______________________________

   Is it positive or negative? ______________________________

4. What is the charge on an electron? ______________________________

   Is it positive or negative? ______________________________

5. What kind of charges were produced around the Van Der Graaf?

6. How about the probe attached to the Van Der Graaf?

Flaws/Ing/Moore
Curie High School
Activity 1
Xerography

7. What kind of charge did you put onto the plate?

Why did it hold onto the toner?

8. Knowing how Carlson first made his copy, how do the Xerox copies that we have today put an image onto the plate? (Look at the copiers in the library.)

9. What in the copier helps to enlarge an image?

10. Why do your hands and the air in the room have to be dry?

PHYS-MA-TECH

AN INTEGRATED PARTNERSHIP

XEROGRAPHY MATHEMATICS WORKSHEET

I. Solve:

1. $y = \frac{k}{x}$, for x

2. $F = k\left(\frac{Q_1 \cdot Q_2}{r^2}\right)$, for k

3. $F = G\left(\frac{Mm}{d^2}\right)$, for M

4. $A = \pi r^2$, for r

5. $F = k\left(\frac{Q_1 \cdot Q_2}{r^2}\right)$, for r.

II. Evaluate using the Inverse Square law:

	Q_1	Q_2	1	r	F
6	1×10^3	8×10^2	9×10^9	.2	
7	3×10^{-3}	6×10^5	9×10^9	.5	
8	2.5×10^2	2×10^3	9×10^9	.01	
9	5×10^{-3}	4×10^{-1}	9×10^9	.6	
10	6.5×10^{-7}	1.5×10^3	9×10^9	.25	

Flaws/Ing/Moore
Curie High School
Activity 1
Xerography

ACTIVITY 2: BAR HOPPING: BAR CODING

TECHNOLOGICAL FRAMEWORK: Students discover the basis for bar coding through usage of oscilloscope to read reflectivity. Students will dissect system into simpler units that will be duplicated to demonstrate the bar coding theory.

PURPOSE: The bar code's underlying principle is based on reflection from a laser and the reading of the reflection to interpret data. In this lab, we will cover reflectivity and the reading of bar codes based on reflectivity.

Students will:

1. Use Physics terms to define reflection.
2. Verify the Law of Reflection.
3. Test the reflectivity of envelopes which are different colors using a laser, photovoltaic cells, and an oscilloscope.
4. Calculate the PCR (Print Contrast Ratios).
5. Interpret bar code patterns through:
    a. Graphing
    b. Solving a time problem
    c. Generating bar codes

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:	Physics--Law of Reflection, angle of incidence and reflectance, light ray measurements, wave form recognition, absorption Mathematics--Pattern recognition, angle measurement, use of formulas, graphing Technology--Use of oscilloscope, use of digital multimeter
PRE-REQUISITES:	Light ray models Ratios and percentages Graphing
MATERIALS, EQUIPMENT, APPARATUS:	Lasers Digital oscilloscope (storage type) Photovoltaic cells Mirrors Protractors Chalk dust Colored envelopes Graph paper Markers
TIME FRAME:	Six 40-minute class periods.
TEACHING STRATEGIES:	Students will analyze bar coding system through basic physics concepts. Students will go through reflectivity activities to make their own bar codes. Experiment will be in three parts. Preparation in Mathematics skills and oscilloscope usage prior to lab are suggested.
TEACHING METHODOLOGY:	Students will take reflectivity readings and understand the law of reflection, and percentage contrast ratios between colors. Bar coding and deciphering is the next step.
FURTHER FIELDS OF INVESTIGATION:	Investigate these related fields: Magnetic Readers and Holographic Bar Coding.

Flaws/Ing/Moore
Curie High School
Activity 2
Bar Hopping: Bar Coding

PROCEDURE: To the Instructor

The bar code is a useful and convenient way to manage, store, and process information by labeling and reading it by using a scanner. The underlying principle is the use of reflectivity to decode the bar symbols. The light and dark bands, when illuminated by the laser, will reflect the light at different intensities. There is a mirror that pivots around at a certain rate within the scanner and picks up the reflecting beam from the laser. This beam is directed to a photovoltaic cell and sends a square wave to the computer to match with letters, numbers, etc. (The square waves will correspond to the reflectivity of the color of bars and background.) There is always a start and stop code which will tell the computer system when to start and stop reading the code. These codes appear before and after every code. The information that is stored into the computer can be processed with software designed to meet the company's needs.

The Post Office and other facilities will test for PCR (% Contrast Ratio) which measures the contrast between the envelope (background) and the printed bar code. This ensures that the scanner can distinguish between the printed bar code and its background. In this way, the Post Office will identify mail that can be processed by using scanners and guarantee efficiency of sorting mail by machine.

This lab is divided into three parts. In the first part, students are to infer the Law of Reflectivity. In Part 2, the students are to test for % of reflection off of different color cards, taking noise into account and also finding the best combination of colors to get a good contrast ratio. They can then calculate, using the data already collected, the % of absorption of the laser light for each color to confirm which colors on the cards have the best and worst reflectivity. In Part 3, the students will learn how a scanner works and deciphers the bar codes.

After the lab is completed, tell the students that there are scanners which read at different rates. (This is also covered in the Questions section of the lab in Part 3.) The problem introduced deals with time. The fact is that a scanner which reads large-size bar codes (which are usually used on large objects and may be also read from longer distances) will not be able to read a small-size bar code (such as on a pack of gum).

Here is an analogy: You are told to run alongside a picket fence at a fast pace, and asked how wide each picket is and how wide the spaces in between are. Chances are that running at such a fast pace, you will not be able to tell me. You can, if: (1) I asked you to slow down your pace, or (2) I had increased the width or size of the pickets proportionally. This is a problem with scanners. Those which scan large bar codes will take less time to do so and still get a good reading, but will not be able to read small bar codes because the rate at which they can scan will give a bad reading. (This problem is presented to the students and they may need some guidance.)

Some Information on Photovoltaic Cells:

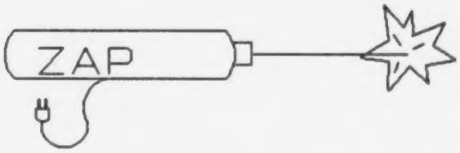
The term "photovoltaic cells" can be broken down into its two constituents: "photo" and "voltaic," to make its definition clearer. "Photo" means light and "voltaic" refers to producing an electro motive force (EMF) or voltage. Therefore, a photovoltaic cell is a solid state device which converts light energy into electrical energy. These cells are also called photo cells or solar cells.

In the bar code experiment, a photovoltaic cell is used as a sensor to detect laser light reflected off of various colors of paper and other materials. Since the voltage produced varies directly with the amount of light placed on the cell, the amount of reflected light can be indirectly measured by connecting the cell to an oscilloscope.

Part 1 - Reflection

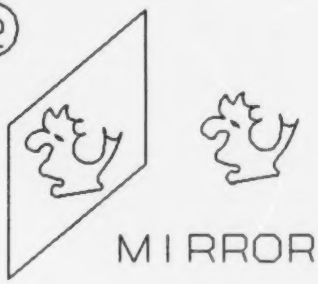
Materials needed:

①



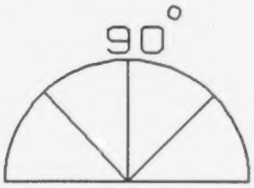
LASER

②



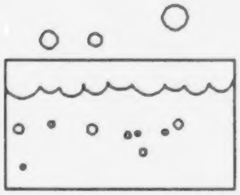
MIRROR

③



PROTRACTOR

④



RECTANGULAR CLEAR CONTAINER W/ SOAP SOLUTION

Procedure:

1. Lay mirror on flat surface with its reflective side up.
2. Set up laser (as in Figure C-2-1, "Laser Set-up") and secure laser to incline with use of tape, etc. Then plug laser into outlet. (Point the laser away from your own or another person's eyes--injury may occur.)
3. Set container with soap solution on top of mirror and turn on laser.

4. Have one person aim the laser at the mirror through the solution and you will notice a reflecting beam. Scatter chalk dust in the air to see beam. Don't stare directly into the beam.

5. The other person should place the protractor onto the mirror, standing vertically with the center point placed at the point of reflection (see Figure C-2-2, "Using Protractor).

6. Record the angle of incidence and the angle of reflection. Do this three times, tilting the laser at different angles. (Fill in Table C-2-1, "Recording Table: Reflection.")

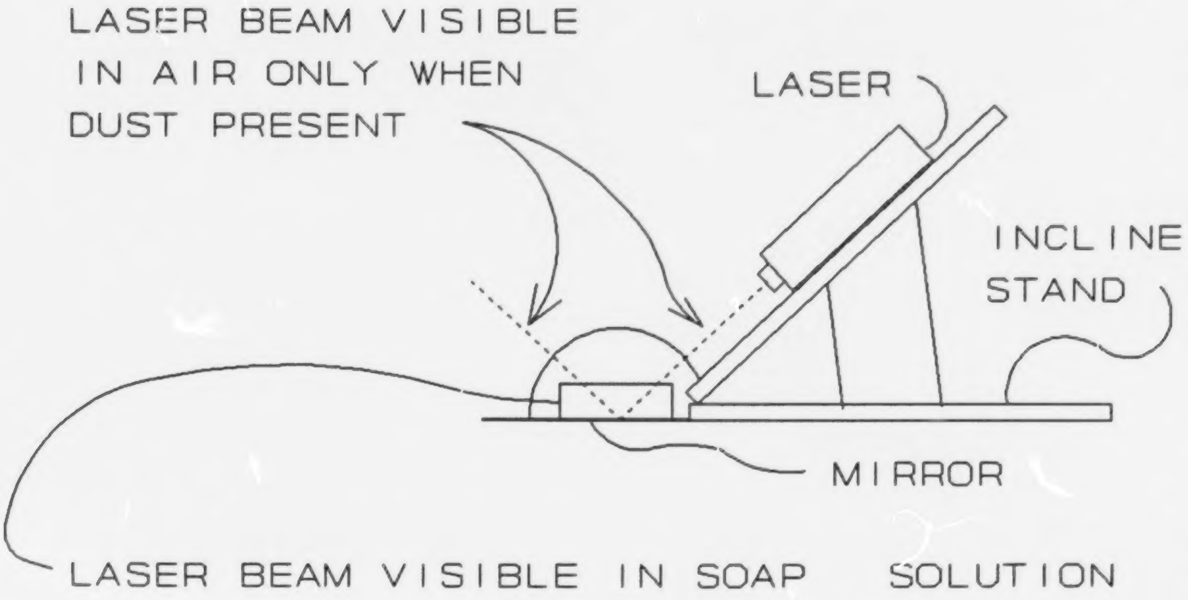

LASER BEAM VISIBLE IN AIR ONLY WHEN DUST PRESENT
LASER
INCLINE STAND
MIRROR
LASER BEAM VISIBLE IN SOAP SOLUTION

Figure C-2-1

Laser Set-up

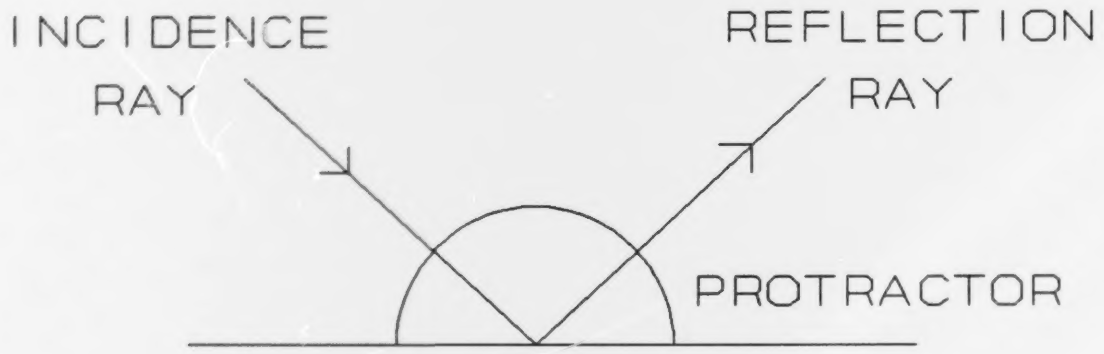

INCIDENCE
RAY
REFLECTION
RAY
PROTRACTOR

Figure C-2-2

Using Protractor

Table C-2-1

Recording Table: Reflection

	1	2	3
θ_i: Angle of Incidence			
θ_r: Angle of Reflection			

POST-LAB QUESTIONS: PART 1 (REFLECTION)

1. What did you notice about the angle of incidence and the angle of reflection angle?

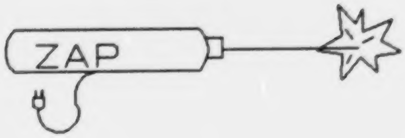
2. If you move the laser beam to another position, what would happen to the reflecting beam?

3. Can you make a guess as to what the Law of Reflection is?

Part 2 - Reflectivity

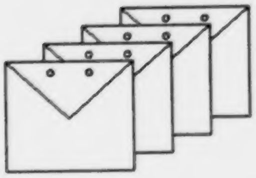
Materials needed:

①



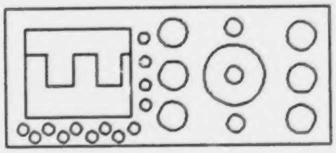
LASER

②



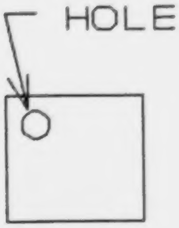
COLORED ENVELOPES

③

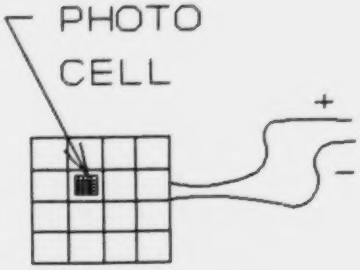


OSCILLOSCOPE

④



DARK CONSTRUCTION PAPER



SOLAR CELL

Procedure:

1. Take a dark-colored piece of construction paper and put a hole in it that would only expose the photo cell when placed over the solar cell. (Use tape to attach to solar cell.) See Figure C-2-3, "Masked Photo Cell."

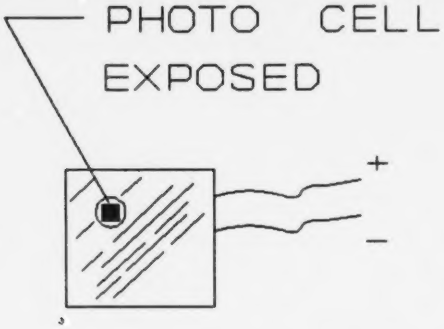


PHOTO CELL
EXPOSED
+
−

Figure C-2-3

Masked Photo Cell

2. Set up the laser and other equipment as in Figure C-2-4, "Bar Code Experiment Setup."

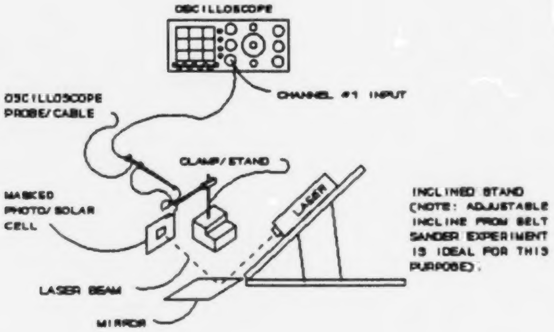

OSCILLOSCOPE
CHANNEL #1 INPUT
OSCILLOSCOPE PROBE/CABLE
CLAMP/STAND
MASKED PHOTO/SOLAR CELL
LASER
INCLINED STAND (NOTE: ADJUSTABLE INCLINE FROM BELT SANDER EXPERIMENT IS IDEAL FOR THIS PURPOSE).
LASER BEAM
MIRROR

Figure C-2-4

Bar Code Experiment Setup

3. Switch oscilloscope on and see if you will get a voltage reading by exposing the masked photo cell to room lights. This is the light you want to ignore ("noise" interference).

The light you want to measure is the light that is reflecting off of the card. Any other light that you pick up on the photo cell (light from the ceiling, windows, etc.) is known as "noise." This noise interferes with the measurements of the reflecting light off of the card and in certain circumstances (too many lights near you) will even "drown out" the reflecting light. This is why we will turn off the lights in the room when doing this experiment and mask the solar cell. Even so, we may still get some noise. See Figure C-2-5, "Light Rays."

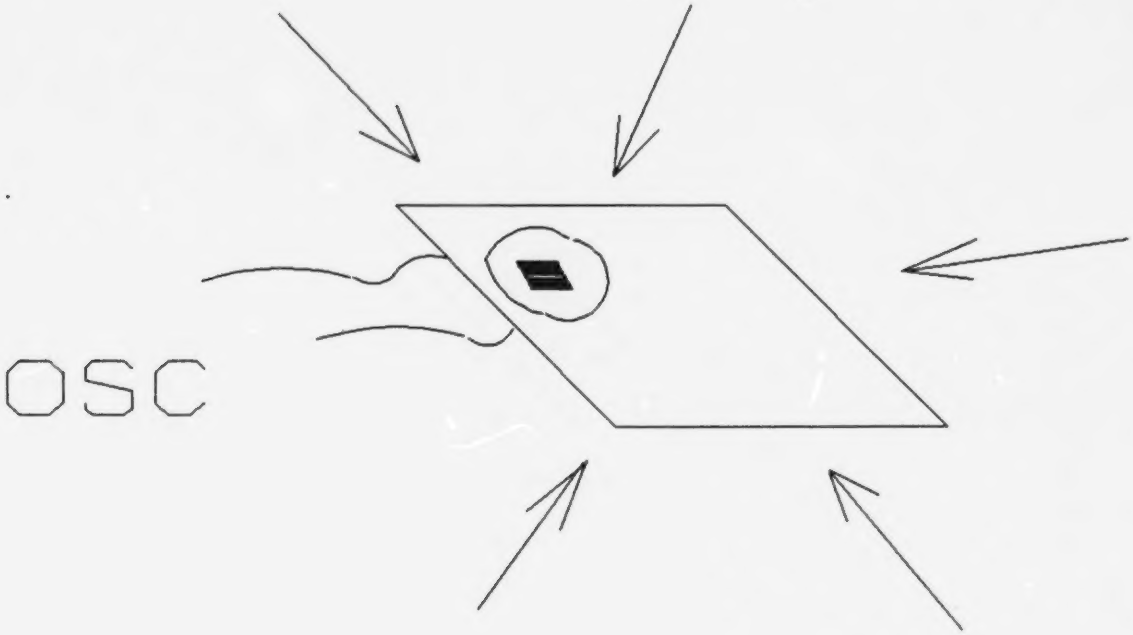


Figure C-2-5

Light Rays

4. To see how much noise is given off in the dark (must have lights off), hold the photo cell at an angle to the envelope (see Figure C-2-6, "Noise") and write down the voltage from the oscilloscope in the noise row of Table C-2-2, "Reflectivity." Now try to hold the photo cell at the same angle and have your partner shine the laser beam so that the reflection hits the photo cell (see Figure C-2-7, "Photo Cell Reflection"). Now put this oscilloscope reading into the "Reflection Off Card" row of Table C-2-2. Do this for all the different color cards, also in Table C-2-2.

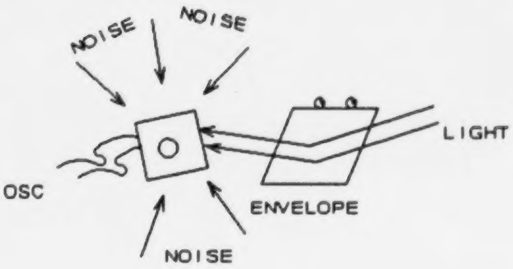


Figure C-2-6

Noise

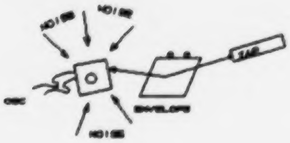


Figure C-2-7

Photo Cell Reflection

5. Your True Reflection is "Reflection Off Card" minus "Noise."

6. After the cards, shine the laser beam at the photo cell directly. This would be your reference value for 100% reflectance. Write down this value in Table C-2-2.

Calculate % of Reflection

$$\% R = \frac{\text{Reflectance off card - noise}}{\text{Reflectance Reference}}$$

Table C-2-2

Reflectivity

	WHITE									BLACK
% REFLECTED										
LASER REFERENCE (V)										
TRUE REFLECTION										
REFLECTION OFF CARD (V)										
"NOISE" (V)										

Bar code scanners read the reflections off of your bars, both black and white, and will show up as waves on a scope. The black bars are usually printed onto a white background (but not necessarily so) and the scanner will pick up a drastic difference. If you had printed black colored bars on a black background, your scanner will not pick up any differences (there is only one type of reflection from one color). This is equal to no information. Even if two colors were similar, the scanner may not pick up any information, so there must be a limit between any two colors you can use. This is expressed as a ratio called:

Print Contrast Ratio (PCR)

$$PCR=\frac{R_w-R_p}{R_w}\ x\ 100$$

R_w = Reflectance of background (envelope)

R_p = Reflectance of ink (bar code)

Calculate the PCR between black ink on different color paper to see which is the best combination. Use the Adjusted Reflection Values from Table C-2-2. Fill in the following information in Table C-2-3, "Reflectivity Calculations."

$$\text{\% Absorption} = \frac{\text{Laser Ref. - True Reflection}}{\text{Laser Ref.}}\ x\ 100$$

Table C-2-3

Reflectivity Calculations

PCR										
Reflected Value of Black Ink										
Reflection Value of Cards										
% Absorption										

POST-LAB QUESTIONS: PART 2 (REFLECTIVITY)

1. Which color is giving the best reflective value?

2. Which color is giving the worst reflective value?

3. Compare the colors of the two above and explain why one would reflect more than the other.

4. Why would we want the laser to scan the colors with the most contrast?

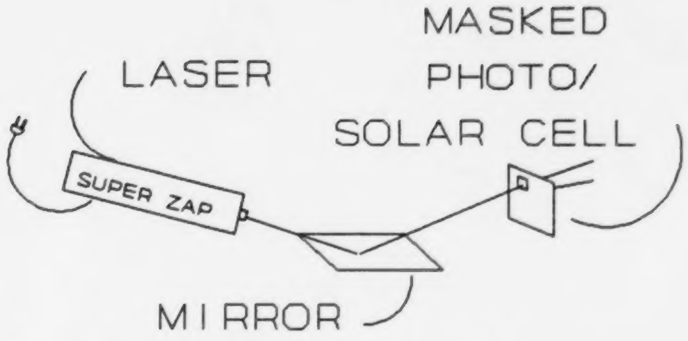
5. Which two colors would give the best PCR? the worst (not including black on black)?

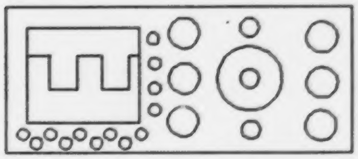
6. Order the pairs of colors with black ink from worst contrast to best.

7. What is the relationship between % Reflectance and Absorptivity?

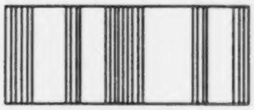
Part 3 - Bar Code Readers

Materials needed:

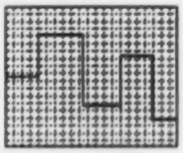




OSCILLOSCOPE (WITH DIGITAL STORAGE)



BAR CODES



GRAPH PAPER

Have you ever been to the supermarket and seen a laser scanner? Chances are that you have. The price tag on the items that you bought were scanned by one. The scanner read the bar codes and the information was decoded by the computer. Let's see what the computer gets from the scanner.

Procedure:

1. In Table C-2-4, "Bar Code Graph," graph the bar code in Figure C-2-8, "Sample Bar Code ." (The bar code is for the letter Z.) The bar is divided into light and dark bands.

2. This is how you will start to graph. There are wide (double) bands and single bands (both black and white). Look at the bar code and identify these:

   How many are wide? black_____ white_____

   How many are single? black_____ white_____

3. Look back at your reflection values for black and white.

   black_____ (volts) white_____ (volts)

4. For every dark band on the bar code, shade in the column on the graph (Table C-2-4) up to that voltage value. Do the same with the white band.

   For wide bands, shade in two columns (they are two times as wide).

5. You should end up with a square wave. (This is what the computer reads.)

Deciphering:

6. Hook up the digital storage oscilloscope to the first one as shown in Figure C-2-9, "Oscilloscope Hookup."

7. The instructor will give you a specific letter for you to draw out (on another sheet of paper). These will be given to other groups to see if they can decipher it on the digital storage oscilloscope.

8. Follow the procedure below in order to get a still trace of your bar code on the digital storage oscilloscope.

   Step 1: One student positions the bar code to be scanned, flat on the mirror in front of the laser beam (ready to slide the bar code through the beam immediately after he calls out "Go").

   Step 2: (for Steps 2-3, refer to Figure C-2-10, "Manual Trigger Controls, Hitachi Digital Storage Oscilloscope, Model VC 6015") regarding manual trigger control.

   a. A second student must put the DISPLAY control lever "C" in the "STORE" position (the one in the middle), and

   b. Push and hold in the "READY" button "B" until your partner says "GO" (then you must release it). When you press the READY button, the ready light "A" should be on and goes off when you release it.

   c. As soon as a trace appears on the oscilloscope, the second student moves the display lever "C" into the "RECORD" position (right-hand side), which freezes the trace on the oscilloscope.

      This two-person team will probably have to repeat these steps several times as well as adjust the oscilloscope sweep (Time/Div) settings, in order to get a satisfactory bar code trace.

   Step 4: Identify the black and white bands by looking at the waves. Draw the square waves (in Table C-2-5, "Square Wave Bar Code Table") and number and label the axis.

9. By looking at the square wave generated on the oscilloscope, identify the letter or number. (Match this with the bar code symbols shown in Table C-2-6, "Code 39 Code Configuration.")

Table C-2-4

Bar Code Graph

Note: Numerical increments indicate volts.

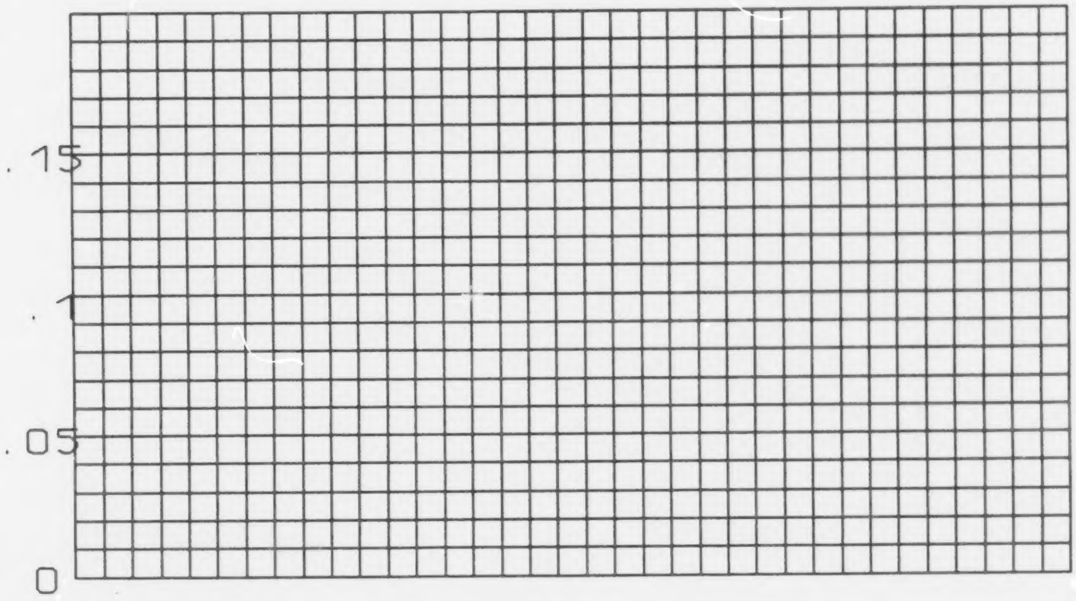


Figure C-2-8

Sample Bar Code

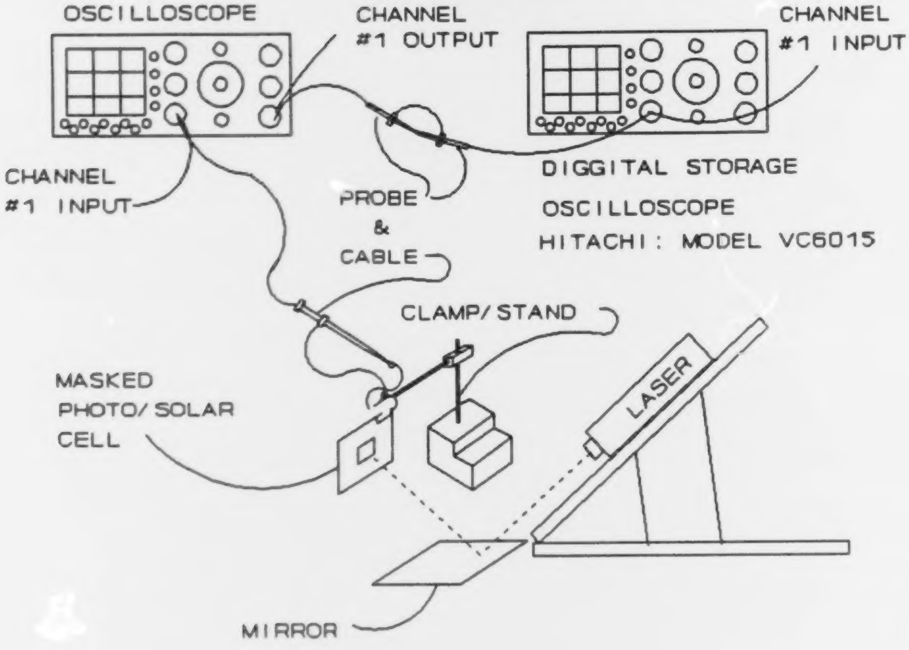

OSCILLOSCOPE
CHANNEL #1 OUTPUT
CHANNEL #1 INPUT
CHANNEL #1 INPUT
PROBE & CABLE
DIGGITAL STORAGE OSCILLOSCOPE HITACHI: MODEL VC6015
CLAMP/STAND
MASKED PHOTO/SOLAR CELL
LASER
MIRROR

Figure C-2-9

Oscilloscope Hookup

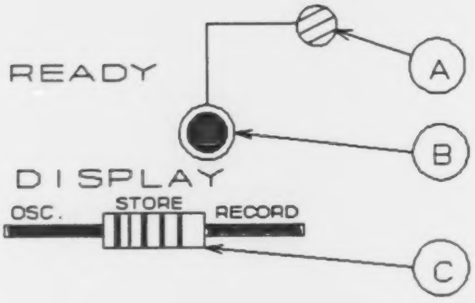

READY
A
B
DISPLAY
OSC.
STORE
RECORD
C

Figure C-2-10

Manual Trigger Controls
Hitachi Digital Storages Oscillator,
Model VC 6015

Table C-2-5

Square Wave Bar Code Table

CHAR.	PATTERN	BARS	SPACES	CHAR.	PATTERN	BARS	SPACES
1		10001	0100	M		11000	0001
2		01001	0100	N		00101	0001
3		11000	0100	O		10100	0001
4		00101	0100	P		01100	0001
5		10100	0100	Q		00011	0001
6		01100	0100	R		10010	0001
7		00011	0100	S		01010	0001
8		10010	0100	T		00110	0001
9		01010	0100	U		10001	1000
0		00110	0100	V		01001	1000
A		10001	0010	W		11000	1000
B		01001	0010	X		00101	1000
C		11000	0010	Y		10100	1000
D		00101	0010	Z		01100	1000
E		10100	0010	–		00011	1000
F		01100	0010	●		10010	1000
G		00011	0010	SPACE		01010	1000
H		10010	0010	★		00110	1000
I		01010	0010	$		00000	1110
J		00110	0010	/		00000	1101
K		10001	0001	+		00000	1011
L		01001	0001	%		00000	0111

Table C-2-6

Code 39 Code Configuration

This table is reproduced with the permission of Intermec Corporation, Arlington Heights, Illinois. Copyright 1989.

POST-LAB QUESTIONS: PART 3 (BAR CODE READERS)

1. Identify the bar codes shown in Figure C-2-11, "Sample Word Bar Code." (What does it spell?)

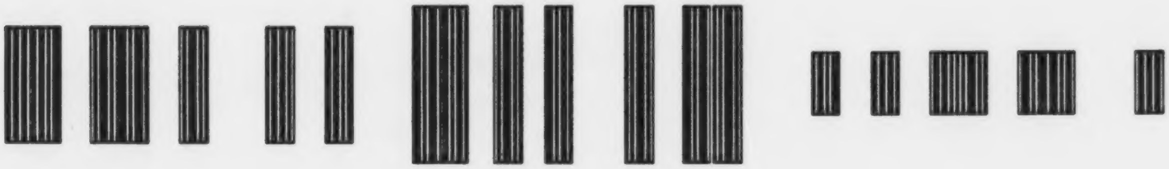


Figure C-2-11

Sample Word Bar Code

2. Does it matter if the bands are long or short? Why? The bar codes on the price tags at the store are long. Why would it be an advantage to make it so?

3. Here are two bar codes that are the same; they only differ in size (see Figure C-2-12, "Variable Size Bar Codes." There are also the waveforms for them, with the reflectivity on the y-axis. Let us use time as the x-axis because the little mirror in the scanner moves around at a certain rate to scan. Some scan faster and some scan slower.

    a. Which one would we use for the big bar code? Why?

    b. If the scanner read the big bar code in 12 milliseconds, would it read the small bar code ? Would it be at a faster rate or slower rate?

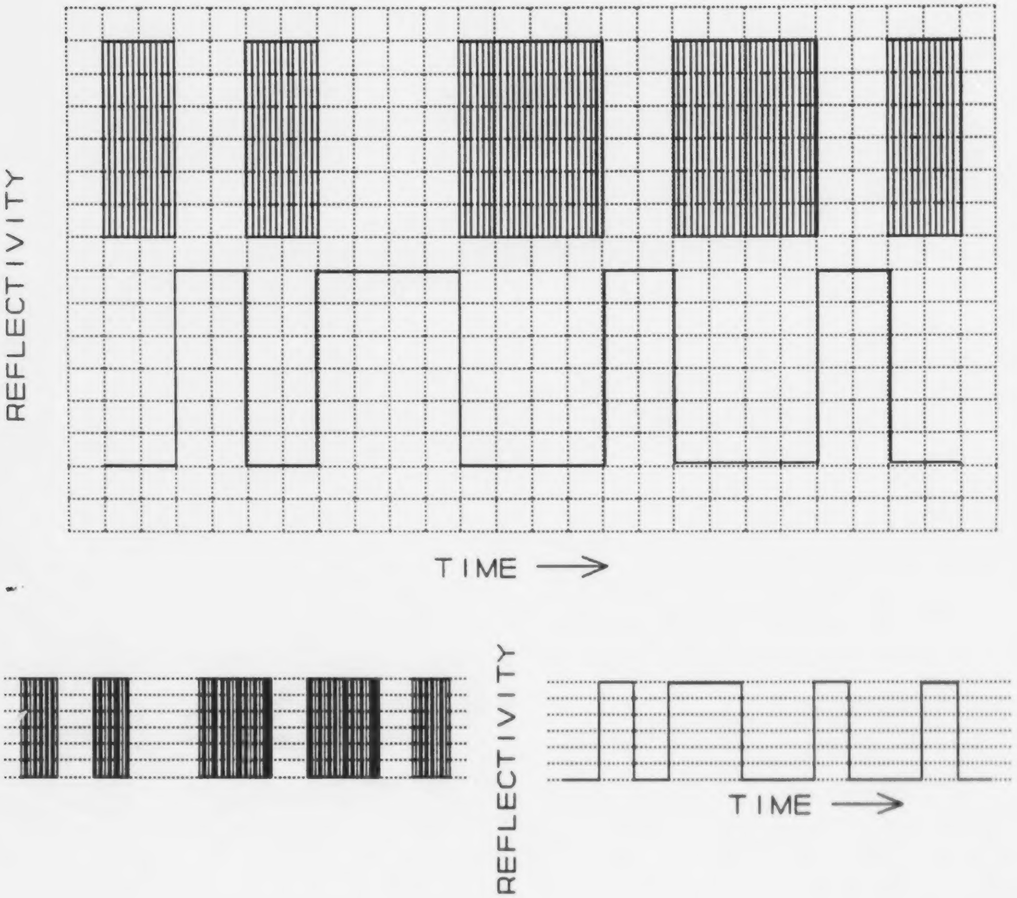

REFLECTIVITY
TIME →
REFLECTIVITY
TIME →

Figure C-2-12

Variable Size Bar Codes

ANTICIPATED PROBLEMS:	In Part 1, students may have difficulty measuring angles with use of chalk dust. In Part 2, students must adjust photovoltaic cell to obtain maximum reflection for accurate reading.
METHODS OF EVALUATION:	Quizzes Worksheets
FOLLOW-UP ACTIVITIES:	Students will bar code their names using Code 39 Students will bar code textbooks to inventory control using ISBN code Students will look at schools' tardy system bar code reader Visit the post office
REFERENCES, RESOURCES, VENDORS:	Palmer, Roger C. (1989). The Bar Code Book. Petersborough, NH: Helmers Publishing, Inc. Allais, D. C. (1989). Bar Code Symbology. Arlington Heights, IL: Intermec Corporation. U.S. Government. Automation and Retail Equipment: (Publication No. 150). (n.d.) Washington, DC: Office of Operational Requirements, 475 L'Enfant Plaza, SW, Washington, DC 20260-7320. Intermec Corporation 3060 Salt Creek Lane, Suite 119 Arlington Heights, IL 60005 Contact: Michael J. Lovelace (708) 255-7767 U.S. Postal Service (local office)

BAR CODING MATHEMATICS WORKSHEET

Introduction:

The code is an interesting application of modular arithmetic and a "form" of binary representation.

POSTNET: POSTal Numerical Encoding Technique is the bar code used by the United States Post Office. Each extended zip code is represented by a 52-character length bar code. Vertical bars have two possible lengths, long and short. Each digit is represented by a block of five bars--two long bars and three short bars. The two extreme ends are always long. They are called "frame bars" and have no numerical value. Extended zip codes have nine digits and a tenth digit for error correction. Since the first and last digits are ignored, there are ten blocks of five bars.

Using a combination: $\begin{matrix}5\\2\end{matrix} = \frac{5.4}{1.2} = \frac{20}{2} = 10$

and there are 10 digits that need to be represented. There is a 1-1 correspondence between all possible arrangements of two long bars and three short bars and ten digits.

Long bars = 1 Short bars = 0

"2 out of 5" coding

Decimal Digit	Bar Code
1	00011
2	00101
3	00110
4	01001
5	01010
6	01100
7	10001
8	10010
9	10100
0	11000

Each set of the five positions are weighted from left to right with a value of 7, 4, 2, 1, and 0.

Example: $1\ 0\ 0\ 1\ 0 = 7.1 + 4.0 + 2.0 + 1.1 + 0.0 = 7 + 0 + 0 + 1 + 0 = \underline{8}$

Thus, 10010 is the representation of 8.

Check digit calculation:
Let the 9-digit zip code be represented by
a + a + a + a + a + a + a + a + a

Let C be the check digit for this zip code.
C is the digit which satisfies
a + a + a + a + a + a + a + a + a + C = 0 module 10

That is, the check digit is found by adding up the 9 digits in the zip code and finding the number needed to round to the next multiple of ten.

Example: 60629-4945 = 6 + 0 + 6 + 2 + 9 + 4 + 9 + 4 + 5 = 45

Check digit is 5 because 45 + 5 = 50 (i.e., next highest multiple of ten)

Once the location of an error is known, the check digit permits the correction of any single error in reading the bar code.

The advantages of using bar-coded zip codes for mailing in business and industry are:

- Processed faster because sorting is easier and more efficient
- Delivery is more accurate
- Turnaround is faster
- Lowers operating cost:
  - Automation cost is $2.50 per 1,000 pieces of processed mail
  - Mechanization cost is $13.20 per 1,000 pieces of processed mail
  - Manual labor cost is $34.70 per 1,000 pieces of processed mail

List three advantages for business or industry to use bar coding for their mail:

Convert the following bar codes to zip codes:

Mr. Robert E. Schneider
Curie Metro High School
4959 South Archer Avenue
Chicago, Illinois

Mr. Huskie
Northern Illinois University
DeKalb, Illinois

Mr. Rogers
The "Neighbor Hood"
Schenectady, New York

Mickey Mouse
Walt Disney World
Orlando, Florida

Paul Revere
Midnight Ride Lane
Boston, Massachusetts

Calculate the following percentages:

Manual Cost/Mechanization Cost________________________________

Mechanization Cost/Automation Cost____________________________

Manual Cost/Automation Cost___________________________________

What is the bar coding that the U.S. Post Office uses?

____

ACTIVITY 3: CRYOGENICS

TECHNOLOGICAL FRAMEWORK: Students will provide low temperatures and observe the effects on living systems. Students discover how to make ice without the use of a refrigeration unit.

PURPOSE: To observe the effects of temperature changes on the metabolism of a life form and record the heat loss at equal time intervals.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--Temperature change, heat loss, physical change of the state of water

Mathematics--Graphing

Technology Skills--Tied to the ice cutting lab

PRE-REQUISITES: Reading of temperature scale (thermometer)

MATERIALS, EQUIPMENT, APPARATUS: Beaker, ice cubes, salt, water, test tube and stopper, stirring rod, thermometers (2), eye dropper, cotton balls, fruit flies

TIME FRAME: One 40-minute class period.

TEACHING STRATEGIES:	Instruction by creating a cold environment and observing its effects on fruit flies. The cold environment is created by the making of ice without a freezer unit, so that students will understand heat loss.
TEACHING METHODOLOGY:	Inquiry to what is cryogenics, and what are the effects on living systems. Making of ice without freezer gives insight on heat loss. Observations are crucial.
FURTHER FIELDS OF INVESTIGATION:	Study super conductvity under low temperatures Animal hibernation Water crystal formations Gas liquification

PROCEDURE:

Introduction:

The study of heat introduces us to a relatively new field of study called "cryogenics." Cryogenics is the study of materials at very low temperatures. Super-conductivity is the most recent development within that field. There are also biological applications. The most widely known is that of preserving body tissues and fluids in a deep freeze to be revived again at a later time.

In this lab, the students will do just that! They will gradually lower the temperature of a test tube containing fruit flies until all metabolic activity ceases. The students will then let the test tube warm gradually until the fruit flies recover from their suspended state. They will learn the correlation between metabolic rate of fruit flies and temperature through observation of activity. The instructor then has an opportunity to discuss and teach topics regarding biophysics. The students may read articles in science journals and do research reports if the instructor wishes.

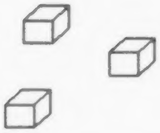
The second concept for students to grasp is that of heat loss. It may be confusing for students to understand or envision that heat may be lost from cold objects. Students tend to associate heat with high temperatures. Students will add salt to ice in a beaker and record temperatures at marked intervals to see that heat can be lost from cold objects as well. Students will visualize heat loss by watching a test tube of water freeze and seeing the fruit flies go into suspended animation.

The task of getting the fruit flies into the test tube will probably be the biggest problem for students. Fruit flies will tend to go into the water in the test tube so it is important to have a mesh or screen in between them. Also, give plenty of room between water and fruit flies due to expansion when water freezes. Students need to mass water before lab also.

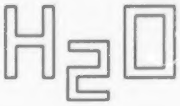
The instructor should be teaching heat loss or have finished that section before doing this lab. Explain that the heat loss of the fruit flies may not be the same as that of the ice water. (The fruit flies are there for the purpose of correlating metabolic activity with temperature.

Materials needed:

①
BEAKER

② 
ICE CUBES

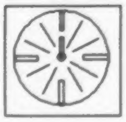
③
SALT

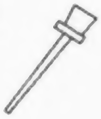
④ 

⑤
TEST TUBE & STOPPER

⑥
STIRRING ROD

⑦
THERMOMETER

⑧ 
TIMER

⑨ 
EYE DROPPER

⑩
COTTON BALLS

⑪
FRUIT FLY

To Prepare Flies

1. Take a paper towel and wrap it around the thermometer. Wet the stopper hole and with a slight twisting motion, push the thermometer through. (Adjust so that it reaches near the bottom of the test tube.) See Figure C-3-1, "Positioning Thermometer."

2. Carefully put in fruit flies. (Don't injure them.)

3. When all the flies are on the sides of the test tube, use your eye dropped to put in __________ ml of H_2O. (Do not drown them and try not to let any out.) See Figure C-3-2, "Adding H_2O."

4. Take a cotton ball and put a hole in the middle of it with your thermometer (should look like a donut). Your thermometer will fit in it. See Figure C-3-3, "Preparing Cotton Ball."

5. Take the cotton ball and push it down into the test tube until you get about 1 1/2" above the water. (Do not crush the flies on the sides nor push them into the water.) Now, slide the thermometer through the cotton ball and into the water. The stopper should fit on top. (See Figure C-3-4, "Completed Test Tube Set-up."

6. Read the temperature and record in Table C-3-1, "Cryogenics Table."

   All flies should be alive at this point.

7. Take large beaker and fill with ice. Add water about half way. See Figure C-3-5, "Beaker with Ice and Water."

8. Put in thermometer and take temperature reading. Record in Table C-3-1.

9. Put in __________ of salt, and then set the test tube in the middle. At this point, stir the salt and ice mixture. (Stir with the stirring rod only.)

10. Take the temperature of the beaker and the test tube every 5 seconds and record the temperature of both. See Figure C-3-6, "Recording Temperature."

    For the test tube, take temperature until water freezes only.

    For the beaker, take temperature until it stabilizes.

    Stir salt water and ice constantly.

11. Also take special attention of activity of flies, i.e., at what temperature they become active, etc.

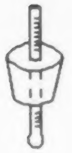


Figure C-3-1

Positioning Thermometer

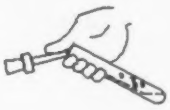


Figure C-3-2

Adding H_2O

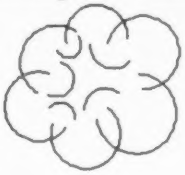


Figure C-3-3

Preparing Cotton Ball

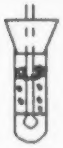


Figure C-3-4

Completed Test Tube Set-up

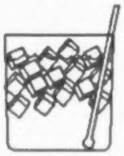


Figure C-3-5

Beaker with Ice and Water

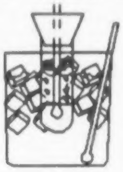


Figure C-3-6

Recording Temperature

Table C-3-1

Cryogenics Table

Time (5 sec)	Test Tube (°C)	Beaker (°C)
0		
5		
10		

Mass of H_2O in test tube __________ grams.

Revival

Remove the test tube from the ice water bath and let it melt at room temperature. The flies are in suspended animation at this time and will not move until the temperature is raised.

Try not to knock any of the flies into the water by bumping the test tube too hard.

1. Take the test tube's temperature every 10 seconds and record them in Table C-3-2, "Revival Chart."

   Also record the activity level of the flies with the symbols below:

☆	totally recovered
♉	quite mobile
〰	mobile
✿	slow
♏	dragging
∾	twitching
✶	frozen

2. Once the flies have recovered, please put them back into their containers. The teacher will show you how.

Table C-3-2

Revival Chart

Time (S)	Temperature (°C)	Activity Level
0		
10		
20		

Calculations

Now to find out how much heat is lost by the water we use the equation:

$$Q = mc\Delta T$$

To find out how much heat is lost per time, we use: (heat flow rate)

$$\frac{Q}{\Delta t}$$

Q: heat
m: mass
C: specific heat
T: temperature
t: time

Calculate: Find Q and $Q/\Delta t$

mass of H_2O __________

initial temp. of water __________

specific heat of H_2O __________

final temperature of water __________

initial time __________ final time __________

Show work here:

$Q =$ __________

$\frac{Q}{\Delta t} =$ __________

ANTICIPATED PROBLEMS:	Give ample space between high water level and cotton ball, in anticipation of water expansion. Don't let fruit flies go A.W.O.L.!!! Colleagues will talk about you.
METHODS OF EVALUATION:	Quiz at end of lab. Teachers will evaluate the quality of the lab worksheets.
FOLLOW-UP ACTIVITIES:	Argonne National Laboratory field trip to see cryogenics and super conductivity.
REFERENCES, RESOURCES, VENDORS:	J. H. Bell. (1963). Cryogenic Engineering. Englewood Cliffs, NJ: Prentice-Hall. F. Holt & G. Ammann. (1990). Cryogenics. The Physics Teacher, 28, 321-323. Wards Biology 5100 W. Henrietta Road P.O. Box 92912 Rochester, NY 14692-9012 (800) 962-2660 (for fruit flies)

POST-LAB QUESTIONS: CRYOGENICS

1. Define exothermic and endothermic.

2. What happens to the temperature in the test tube (is the process endothermic or exothermic?)?

3. Lowest temperature recorded for beaker? __________

   Lowest temperature recorded for test tube? __________

4. How long were the fruit flies active? __________

5. How long did it take the fruit flies to revive? __________

6. What changes do you think had occurred in the fruit flies' body during the freezing process?

7. How much heat was lost in the test tube? Is the heat loss by the fruit flies about the same as the water?

8. What would be a benefit for freezing your body?

9. Graph Temperature vs. Time for the beaker.

10. Graph Temperature vs. Time for the test tube.

PHYS-MA-TECH
AN INTEGRATED PARTNERSHIP

MATHEMATICS WORKSHEET: CRYOGENICS

Literal Equations

Literal equations are equations with two or more different variables, as in formulas.

Using the formula for calculating the heat loss, $Q = mc\Delta T$:

a. Solve this equation for m ____________________

b. Solve this equation for c ____________________

c. Solve this equation for ΔT ____________________

d. In an aerobic workout, the Incredible Hulk, who weighs 112 kg and has a normal temperature of 37 degrees Celsius, had a heat loss of 725 calories. If his temperature increased to 42 degrees Celsius, how many calories did he burn?

____

The temperature in Fahrenheit can be approximated by counting the chirps a cricket makes in one minute, and using the formula, $T = .25C + 37$.

a. Solve the formula for C ____________________

b. Calculate the approximate temperature if a cricket chirps

150 times per minute ____________________

225 times per minute ____________________

c. As the number of chirps per minute increases, the temperature ____________________

Flaws/Ing/Moore
Curie High School
Activity 3
Cryogenics

To convert Fahrenheit temperatures when you know Celsius, use the formula, F = 9C/5 + 32.

a. Solve for C ____________________

b. Calculate Celsius temperature if the Fahrenheit temperature is 23 degrees ____________________

The slope-intercept form a linear equation if y = mx + b, where m is the slope, b is the y-intercept, and (x,y) is a point on the line.

a. Solve for b ____________________

b. Solve for x ____________________

c. If the slope is -3 and the y-intercept is 10, write the equation of the line. ____________________

d. Given the point (7, -1) and a y-intercept of 8, find the slope of the line. ____________________

ACTIVITY 4:	CENTRIFUGE
TECHNOLOGICAL FRAMEWORK:	Students separate materials with the use of a centrifuge and at the same time learn how much force is exerted through the speed of rotation.
PURPOSE:	To demonstrate density and centripetal forces of liquids and solids spinning in a centrifuge to measure rotational speed and the number of revolutions in a given time period.
ILLINOIS LEARNER OUTCOMES:	As a result of their schooling, students will have a working knowledge of: •The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society. •The principles of scientific research and their application in simple research projects. •The processes, techniques, methods, equipment, and available technology of science.
CONCEPTS:	Physics--to show density of water, to demonstrate rotational equilibrium, centripetal acceleration and force, and uniform circular motion. Mathematics--usage of equations. Technology--stroboscope usage and reading.
PREREQUISITES:	Calculate centripetal acceleration in "g's."
MATERIALS, EQUIPMENT, APPARATUS:	Centrifuge, test tubes, stroboscope, water, sand, corn starch
TIME FRAME:	Three 40-minute class periods

TEACHING STRATEGIES:	Students will separate materials with a centrifuge and learn how it separates. They will also measure the speed of rotation and calculate G-Force.
TEACHING METHODOLOGY:	Students use centrifuge to separate materials and a stroboscope to measure rotational speed--all hands-on activity until the calculation of G-Force. Students need to learn through this activity what G-Force is.
FURTHER FIELDS OF INVESTIGATION:	Friction welding Blood purification Dust/air transportation system Amusement park rides Space orbiting simulation Car wheel aligning

PROCEDURE:

Safety: Make sure centrifuge is balanced by having test tubes placed in pairs opposite each other or breakage may occur. Have cover on centrifuge when spinning, and do not touch.

Centrifuge

To the Instructor:

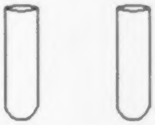
This lab is designed to help the students understand what a centrifuge is used for, how it works, and most importantly, show that they are able to analyze the system using Physics concepts and formulas. The students need a general understanding of rotational motion before they begin doing this experiment. Most of the equations are already given, but it is the instructor's responsibility to make sure the students know why and how to use them.

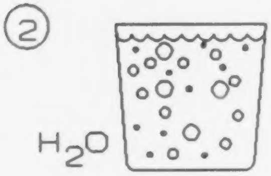
In Part 1 of the lab, the students' objective will be to calculate and find angular acceleration and angular distance. The students can obtain initial and final angular velocity and time by usage of a stroboscope and a timer. (Introduction to stroboscopic usage is assumed prior to doing the lab.)

In Part 2 of the lab, the student will calculate the centripetal force that caused separation of the different materials they have loaded in the test tube. In this part, it is essential that the student understands what is meant by "G-Force." Explain that it is not a force, but a reference to the acceleration of gravity expressed as a multiple. Also, for this part, the student should be able to solve for sides of a triangle using sine and cosine (prior to lab). Radian measurement should also have been taught prior to doing the lab. Suggested measuring tool is the caliper instead of a ruler (some students may have difficulty obtaining accurate measurements with the ruler).

It is important to have the students understand and distinguish between angular acceleration and centripetal acceleration.

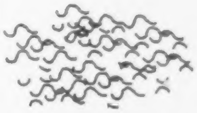
Materials needed:

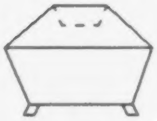
①

TEST TUBES

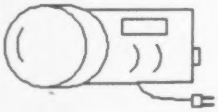
②


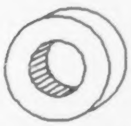
③

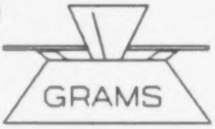
SAND

④

STARCH

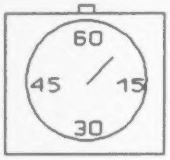
⑤

CENTRIFUGE

⑥

STROBOSCOPE

⑦

MASKING TAPE

⑧


PAN BALANCE

⑨


TIMER

Purpose: In this lab, we will try to find the final angular velocity, angular acceleration, time to reach final angular velocity, centripetal force, and angular distance by using the stroboscope to time the centrifuge's circular motion.

Note: The figures will vary for each substance used.

Part 1

In this part, we are going to find the unknowns listed above on an unloaded centrifuge.

1. Tear off a piece of marking tape and stick it to the side of the centrifuge.

2. Turn on the centrifuge and wait a while until the centrifuge reaches its maximum speed.

3. Turn on the stroboscope and aim it at the centrifuge. Turn the dial on the back slowly until you see two images (this will be at 2 times the speed.) Turn the dial back until you see only one image (this is the speed you want). This speed is given in flashes per minute. Record this information in Table C-4-1, "Rotational Motion" as your final velocity (w_f) in rads/sec. Turn off the centrifuge and also the strobe by turning the ON/OFF dial that is on the front of the strobe. (Don't touch the dial on the back.)

4. Wait until the centrifuge stops; then turn on the strobe and aim it at the centrifuge. We are going to time how long it takes the centrifuge to reach its maximum speed. Since the strobe is already set for the maximum speed, all you need to do is time the centrifuge until the strobe matches the speed. Record the time (t) in sec. in Table C-4-1.

Table C-4-1

Rotational Motion

w_o	w_f	t	α	θ

w_o = initial velocity
w_f = final velocity
t = time
α = angular acceleration
θ = angular distance

Calculate the angular acceleration with the

equation: $\alpha = \frac{w_f - w_o}{t}$

Change $\frac{rev}{s}$ into $\frac{rad}{s}$ → 2π rad = 1 rev

Show
work
here:

Since you found α, you can calculate the number of turns the centrifuge has gone through by using the formula:

$$\theta = w_o t + \frac{1}{2}\alpha t^2$$

Your answer will be in rads. To get the number of turns, divide it by 2π.

Show
work
here:

Part 2

In this part of the lab, we will test the centrifuge for w_o, w_f, α_c, θ, and centripetal force on material at different points. We will also learn about G-Force.

1. Measure out _____ grams of starch and stand on the pan balance and put into the test tube. Also put in _____ grams (ml) of water. Shake it up! Then record the data in kilograms in Table C-4-2, "Substance Massing."
2. Spin the mixture in the centrifuge. Then take it out when they have separated, and measure how far down each of the materials is from the top of the test tube. (See Figure C-4-1, "Separated Substances.")

3. Now calculate how far the material would be from the center of the centrifuge when the test tube is in place. (Use trigonometry to find this.) Since the angle is 45° and we know the distances from the top of the test tube, we can find the horizontal distance. (See Figure C-4-2, "Separation Distance Diagram.")

   Use: $d_a (\cos 45^\circ) = r_a$ and so on. r = radius from the center of the centrifuge. Record r_a, r_b, and r_c in Table C-4-3, "Calculated Separation Distance."

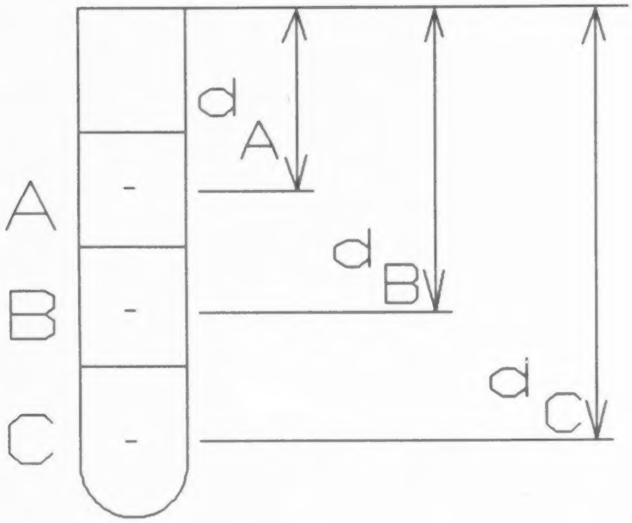


Figure C-4-1

Separated Substance

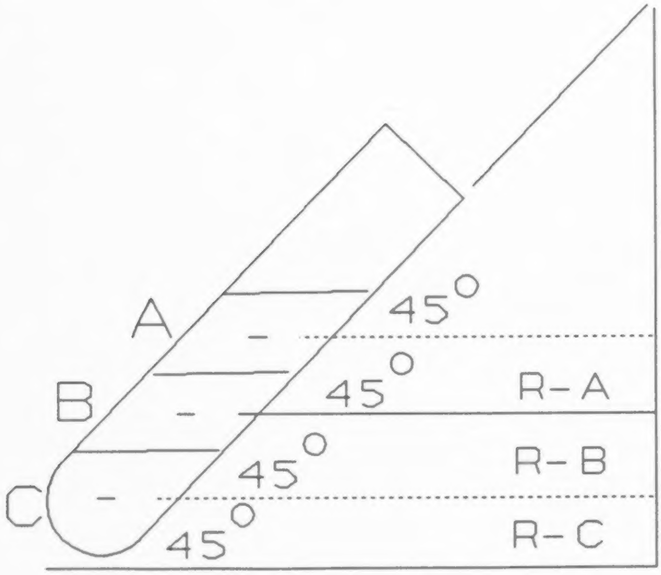

A
B
C
45°
45°
45°
45°
R- A
R- B
R- C
-
-
-

Figure C-4-2

Separation Distance Diagram

4. Now go through steps 1, 2, 3, and 4 in Part 1 to find the final velocity of the system, and the time. Record in Table C-4-4, "Final Velocity Table."

Table C-4-2

Substance Massing

Sand	Starch	Water	
			Mass (kg)

Table C-4-3

Calculated Separation Distance

	d_a	d_b	d_c
Distance (m)			
Radius (m)			
	r_a	r_b	r_c

Table C-4-4

Final Velocity Table

w_o	w_f	t	α_c (a)	α_c (b)	α_c (c)

α = centripetal acceleration

( ) = denotes which material

The centripetal acceleration (α_c) is different for each of the materials because the radius is different for each material.

We use another formula:

$\alpha_c\ (a) = w^2\ r_a$ $\alpha_c\ (a) = w^2\ r_b$ $\alpha_c\ (a) = w^2\ r_c$

Put these into Table C-4-4.

Show
work
here:

5. To find how many times each of the materials went around, we use the following equations. Put these into Table C-4-5, "Revolutions."

$$\theta_a = w_o t + \frac{1}{2}\alpha_a\ t^2$$

$$\theta_a = w_o t + \frac{1}{2}\alpha_b\ t^2$$

$$\theta_a = w_o t + \frac{1}{2}\alpha_c\ t^2$$

These are going to be in radians. Divide by 2π to get revolutions.

Table C-4-5

Revolutions

θ_a	θ_b Revolutions	θc

Show
work
here:

6. Once we have the angular acceleration for each of the materials, we can find the centripetal force on each and translate that into what is known as G-Force.

To calculate centripetal force: F_c (a) = m x α_c

F_c = centripetal force

α_c = centripetal acceleration

a. Force on material a : F_c (a) = ma $\cdot$ α_c (a)

G-Force on material a : F_c (a)/g

F = c(a) ___________

G-Force = ___________

Show
work
here:

b. Force on material b : F_c (b) = m_b $\cdot$ α_c (b)

G-Force on material b : F_c (b)/g

F = c(b) ___________

G-Force = ___________

Show
work
here:

c. Force on material c : F_c (c) = ma $\cdot$ α_c (c)

G-Force on material b : F_c (c)/g

F = c(c) ___________

G-Force = ___________

Show
work
here:

ANTICIPATED PROBLEMS:	Students may have difficulty in measuring the distances with rulers (see Teaching Strategies above).
METHODS OF EVALUATION:	Quizzes and oral questioning
FOLLOW-UP ACTIVITIES:	Great America Physics Day Visit Broadcasting Museum to view videos Astronaut training tapes
REFERENCES, RESOURCES, VENDORS:	Laura Levitt Broadcasting Museum 800 South Wells Chicago, IL (312) 987-1500 Central Scientific Co. 11222 Melrose Ave. Franklin Park, IL 60131-1364 (800) 262-1364 (for purchases of centrifuges) Giancoli, D. C. (1980). Physics. Englewood Cliffs, NJ: Prentice-Hall. Serway, R. A., & Faughn, J. S. (1985). College Physics. Orlando, FL: Holt, Rinehart, & Winston.

PHYS-MA-TECH
AN INTEGRATED PARTNERSHIP

POST-LAB QUESTIONS: CENTRIFUGE

1. What was the maximum speed for the centrifuge that you had?

   In rev/sec?__________ In rads/sec?__________

2. What does a centrifuge do?____

   ____

   ____

3. What is the Physics principle(s) that helps a centrifuge work the way it does?____

   ____

4. What material ended up at the bottom of the test tube?

   ____

5. What material was on top?____

6. What general types of material would be separated into the top layers in the test tube?

   ____

7. How about the bottom layer?____

8. Would separations occur between materials at lower speeds? Explain.

   ____

   ____

   ____

9. What are other uses for a strobe?

10. Give a definition in your own words for G-Force.

PHYS-MA-TECH

AN INTEGRATED PARTNERSHIP

CENTRIFUGE MATHEMATICS WORKSHEET

I. Solve

1. $s = vt + \frac{1}{2} at^2$, for a

2. $v + r + at$, for a

3. $s = vt + \frac{1}{2} at^2$, for v

4. $a = \frac{v}{t}$, for t

5. $\alpha = \frac{w_f - w_o}{t}$, for t

6. $\theta = w_o t + \frac{1}{2} \alpha t^2$, for α.

II. Convert each degree measure to radians. Leave answers as multiples of π.

7. 60° 8. 150° 9. 135° 10. 270°

III. Convert each radian measure to degrees.

11. $\frac{\pi}{3}$ 12. $\frac{2\pi}{3}$ 13. $\frac{3\pi}{4}$ 14. $\frac{5\pi}{6}$

IV. Using a calculator, convert radian measure to degrees. Write answer to four decimal places.

15. 4.2

ACTIVITY 5: COLD CUTS: COMMERCIAL ICE CUBE MACHINES

TECHNOLOGICAL FRAMEWORK: Students must assess the amount of heat and energy needed or given off in an ice cube making machine.

PURPOSE: To demonstrate the principles of operation of a commercial ice cube machine to the students in such a way that they will be able to:

1. Explain the three major steps in making commercial cubes:
    a. Freezing the water into a block.
    b. Moving the ice block to the cutter.
    c. Cutting the block into cubes.
2. Calculate the energy required to:
    a. Freeze the water into ice.
    b. Cut the ice into cubes.
3. Cite four applications of this technological application.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS: Physics--specific heat capacity, electrical energy, heat of fusion

Mathematics--formula substitution, linear equations, absolute values, sign changes, ratios and proportions

Technology Skill--conversion of electrical to heat energy, electrical control

PRE-REQUISITES:
Circuit Building
Meter Reading
Micrometer Reading
Blueprint Reading

MATERIALS, EQUIPMENT, APPARATUS:
Freezing pan with electrical heat tracing
Freezing pan insulator
High-resistance wire ice cube cutter
Ice cube making stand
Low rim ice cube catching pan
Timer
Three-position switch (SPDT)
2 control relays
2 multimeters volt-ohm-milliammeter (V.O.M.)
Freezer
Insulation board/shield
Thermometer
Paper towels
Tap water
Pan balance
Micrometer caliper
Bread board
3 stick-on labels

TIME FRAME: Two 40-minute periods

TEACHING STRATEGIES: Students will experiment to calculate how much energy and heat are needed to make cuts in a block of ice to get ice cubes.

TEACHING METHODOLOGY: Simulation of an ice cube maker. Students follow design and assemble equipment in order to cut the ice block. Measurements are taken for calculations later.

FURTHER FIELDS OF INVESTIGATION:

Commercial ice cube making

Refrigeration/freezer defrosting

De-icing (examples: aircraft wing, propellers, and windshields; pedestrian and vehicle ramps; fluid pipelines and railway switches)

Commercial and residential under-floor heating

COMMERCIAL ICE CUBE MACHINES: PRE-LAB ACTIVITY 1

Introduction:

Commercial ice cube machines take a novel approach to each of the following three processes: freezing water, moving ice, and cubing ice. The commercial ice cube machine freezes water into ice by spraying many layers of fine water mist onto an inclined and sideless refrigerated surface (see Figure C-5-1, "Ice Cube Machine Freezing Chamber--Side View"). The fine mist spray allows for faster ice formation by minimizing the amount of water, and thus the amount of cooling required, to freeze the small water droplets. At the same time, spraying maximizes the water's surface exposed to cooling which further speeds up the freezing process. In fact, the water droplets in this fine spray are frozen before they reach the refrigerated surface just inches away. An ice tray full of water takes longer to freeze because its size requires much more energy removal and the water surface exposed to cooling is much less.

The moving of the ice sheet is novel because it only relies on gravity and defrosting a flat inclined freezer pan. The fine mist water spray, in addition to speeding up the freezing process, also allows a uniformly thick ice sheet to form on the incline without side walls for containment. When the layered ice sheet reaches the proper thickness, the freezer pan is defrosted (heated), allowing the ice sheet to slide down onto the cutting wire grid. Gravity provides a dependable "free" motive force.

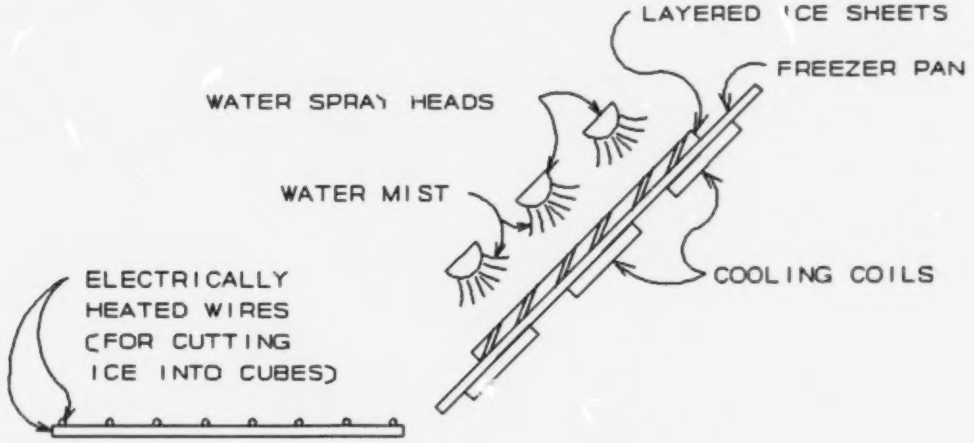


Figure C-5-1

Ice Cube Machine Freezing Chamber--Side View

A containment wall system with the bottom wall movable to allow the ice sheet to slide out would leak and cause problems. The freezer pan can be defrosted by circulating available hot liquid refrigerant in the cooling coils for a short period of time. It can also be defrosted by electrical heating wires, similar to the wires in the ice cutting/cubing grid of the commercial machines or the wires used in the experiment apparatus to both defrost and cut the ice sheet.

Why Commercial Ice Cubes Have Holes:

The ice freezing/cubing technology described in the previous paragraphs is now obsolete, with only a few "old" machines using that method in service today. Modern commercial ice cube machines no longer cut solid ice sheets into cubes--they freeze each cube individually! This one-step process is not only simpler than the preceding process, but also lowers energy usage. This improved process causes the holes in some modern ice cubes.

The following four basic changes were made to the old process: (1) the water spray was inverted, spraying up instead of down; (2) the spray nozzles were sometimes reconfigured from an evenly spaced, straight pattern to evenly spaced circles; (3) the freezer pan was repositioned above the spray nozzles, rather than below; and (4) the previously flat freezer pan was reshaped into evenly spaced patterns, sometimes with cylinders or truncated cones at their center, which lined up directly above each set of circled spray nozzles (see Figure C-5-2, "Inverted Freezer Pan/Spray System for Modern Ice Cube Machine").

With the new process, the spraying, freezing, and defrosting method is the same as the old process. Once the ice cubes fall out of the defrosted freezer pan and are diverted into the bin below, the process is finished without the need for any ice cutting.

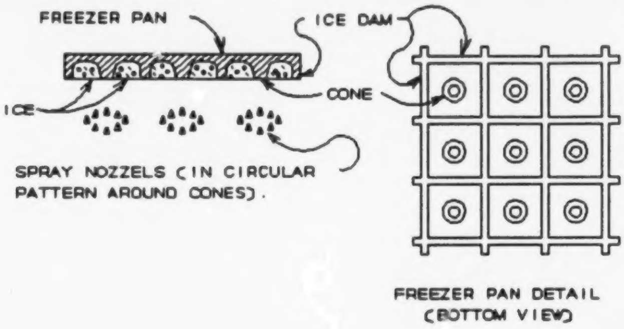

FREEZER PAN
ICE DAM
CONE
ICE
SPRAY NOZZELS (IN CIRCULAR PATTERN AROUND CONES).
FREEZER PAN DETAIL (BOTTOM VIEW)

Figure C-5-2

Inverted Freezer Pan/Spray System for Modern Ice Cube Machine

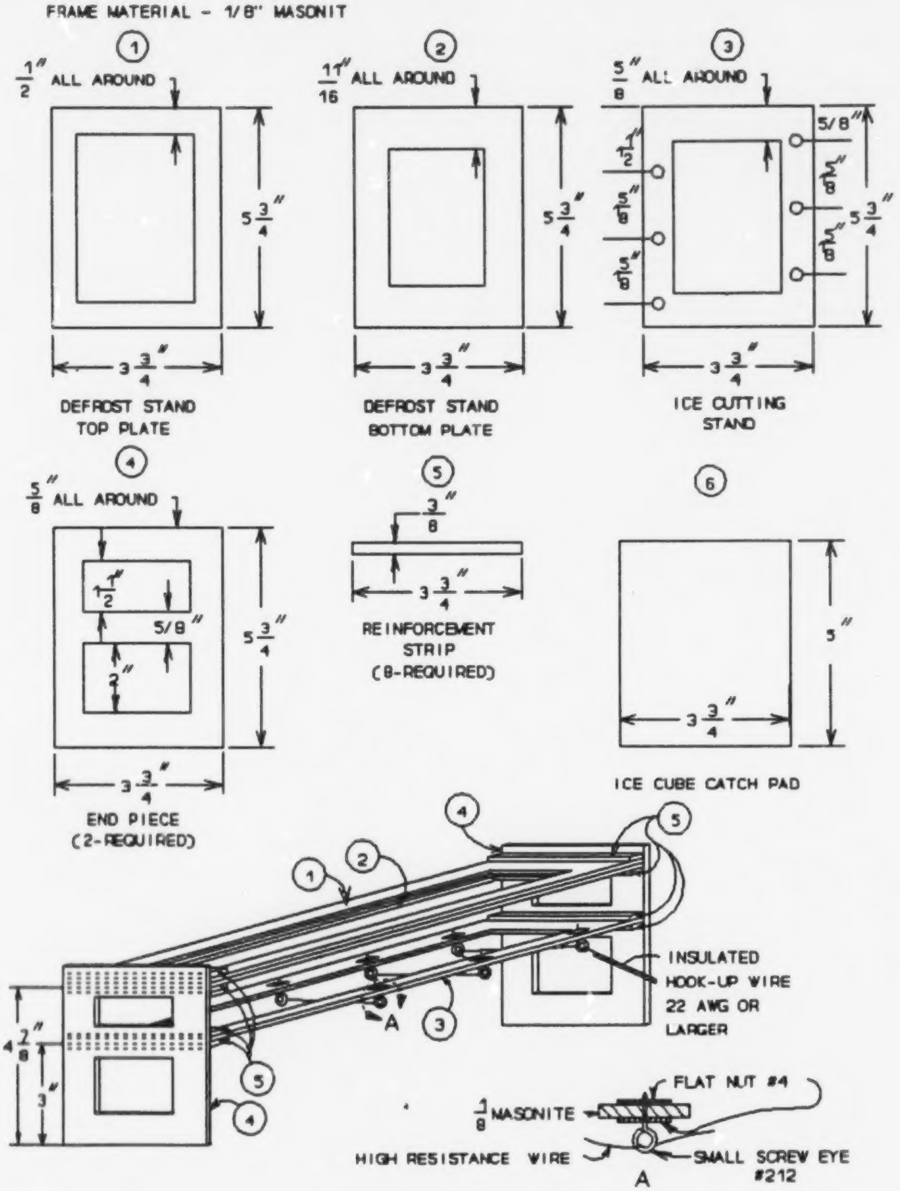

FRAME MATERIAL - 1/8" MASONIT
1
1/2" ALL AROUND
5 3/4"
3 3/4"
DEFROST STAND TOP PLATE
2
11/16" ALL AROUND
5 3/4"
3 3/4"
DEFROST STAND BOTTOM PLATE
3
5/8" ALL AROUND
5/8"
1/2
5/8"
5/8"
5/8"
5/8"
5 3/4"
3 3/4"
ICE CUTTING STAND
4
5/8" ALL AROUND
1/2"
5/8"
2"
5 3/4"
3 3/4"
END PIECE (2-REQUIRED)
5
3/8"
3 3/4"
REINFORCEMENT STRIP (8-REQUIRED)
6
5"
3 3/4"
ICE CUBE CATCH PAD
4
5
1
2
A
3
4 7/8"
3"
5
4
INSULATED HOOK-UP WIRE 22 AWG OR LARGER
FLAT NUT #4
1/8 MASONITE
HIGH RESISTANCE WIRE
SMALL SCREW EYE #212
A

Figure C-5-3

Ice Cutting Machine Components

Construction Notes:

Materials List:

1/8" masonite board - 0.8 sq. ft.
Cyanoacrylate adhesive (super or crazy glue)
High resistance wire - 24 AWG (chromel or nichrome) - 32"
Flat nut #4 - 12 units
Small eye screw #212 - 6 units
Miniature loaf pan - 1 unit
3/4" styrofoam insulation board - 2.8 sq. ft.
Elmer's glue

Comments/Problems:

1. Soldering problem - High resistance (nichrome) will not solder to itself or the aluminum miniature loaf pan. Therefore, the resistance wire must be soldered tc the miniature load pan via small loops of cooper wire which are soldered directly to the pan. Also, when soldering insulated hook-up wire to the high resistance wire, after interlocking the two wires, wrap the hook-up wire around the joint in order to get a good solder.

2. Stabilizing the ice cutting wires - To have taut ice cutting wires, wrap the high resistance wire around the end eye screws after pulling the wire tight.

Wire Lengths:

Hi-Temperature Wire:

1. 1 - 17" - freezer pan

2. 1 - 18" - ice cutting element

24 AWG Conductor

3. 2 - 18" - ice cutting element conductors

4. 2 - 15" - freezer pan conductors

COMMERCIAL ICE CUBE MACHINE: PRE-LAB ACTIVITY 2

This activity is to be completed during the class period prior to the ice cutting experiment.

Note: Ruler must be level with the bottom of the freezer pan.

1. Measure and mark the inside of the freezer pan at 30 mm. See Figure C-5-4, "Freezer Pan: End View."
2. Fill the freezer pan with water up to the 30 mm mark.
3. Place the water-filled freezer pan in a freezer over night in order to have an ice block for the experiment the next day.
4. Place a thermometer in a glass under the slowly running faucet used to fill the freezer pan. Leave the thermometer under the running water for three minutes. Then read and record the tap water temperature in the proper space in Table C-5-2, "Ice Freezing Energy Table" (second row).
5. Dry off and store all equipment used for this activity.

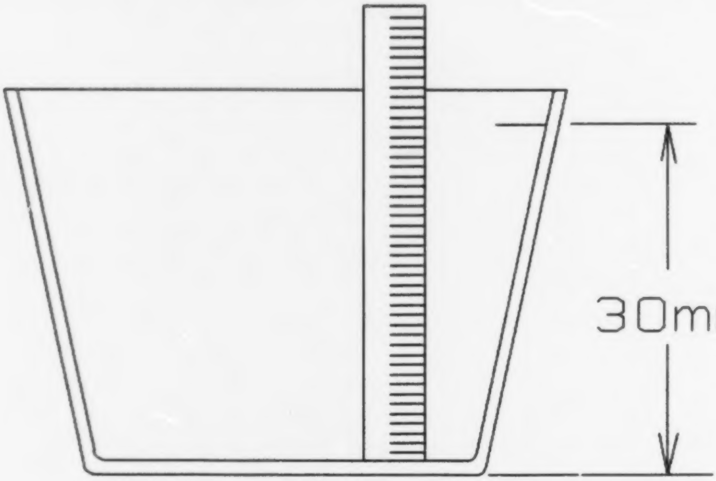


Figure C-5-4

Freezer Pan: End View

COLD CUTS: COMMERCIAL ICE MACHINES LABORATORY EXPERIMENT

Purpose:

The purpose of this experiment is to cut ice cubes out of a block of ice, imitating commercial ice cube machines, and calculating the required energy.

Summary of Procedure:

First, the mass of the ice is measured. This mass, in combination with the water temperature taken the day before, will allow the calculation of the amount of energy required to freeze the ice block. Next, the following information about the ice cube cutter electrical heater is recorded: current, voltage, and time "On." This information will allow the calculation of the total amount of electrical energy used to cut the ice block into cubes. A calculation of the length of heating wire in contact with the ice block during cutting will allow the calculation of the actual electrical energy used to cut the ice. Finally, the volume of ice melted by the heating wires in order to cut the ice block is calculated and used to determine the energy required. This energy required to melt the ice in contact with the heater wires is compared to the actual electrical energy used to cut the ice block.

Caution:

Conduct the experimental steps in the exact order shown! Complete steps 5 through 10 as quickly as possible with the minimum of time used between steps. Heeding this caution will minimize the amount of energy the ice block gets from the warm room which could result in heat energy calculation errors.

Procedure:

1. Connect the control and power circuits, as shown in Figure C-5-5, "Ice Cutting Machine--Electrical Control and Power Diagram," and label the control switch positions accordingly. Note: The freezer pan heater will not be connected until step 6, when the ice block is ready for defrosting. Also, set up the ice cutting apparatus as shown in Figure C-5-6, "Ice Cutting Machine Assembly," without the freezer pan and its insulation.

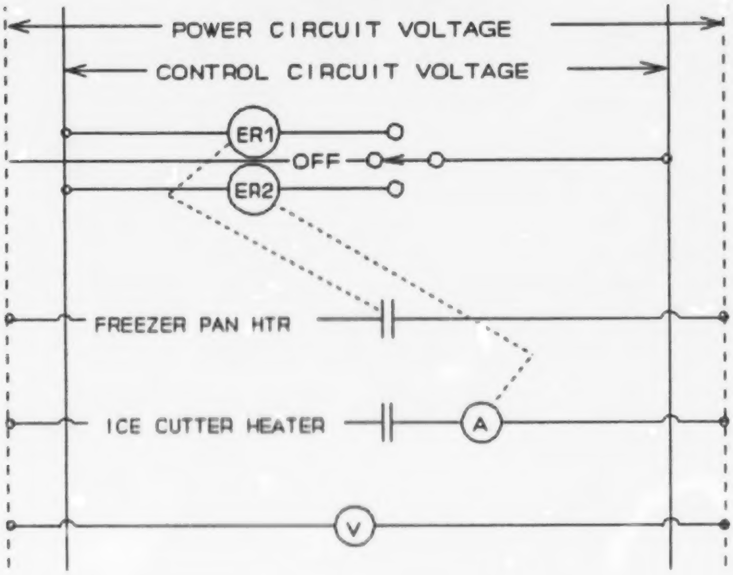

POWER CIRCUIT VOLTAGE
CONTROL CIRCUIT VOLTAGE
ER1
OFF
ER2
FREEZER PAN HTR
ICE CUTTER HEATER
A
V

Figure C-5-5

Ice Cutting Machine--Electrical Control and Power Diagram

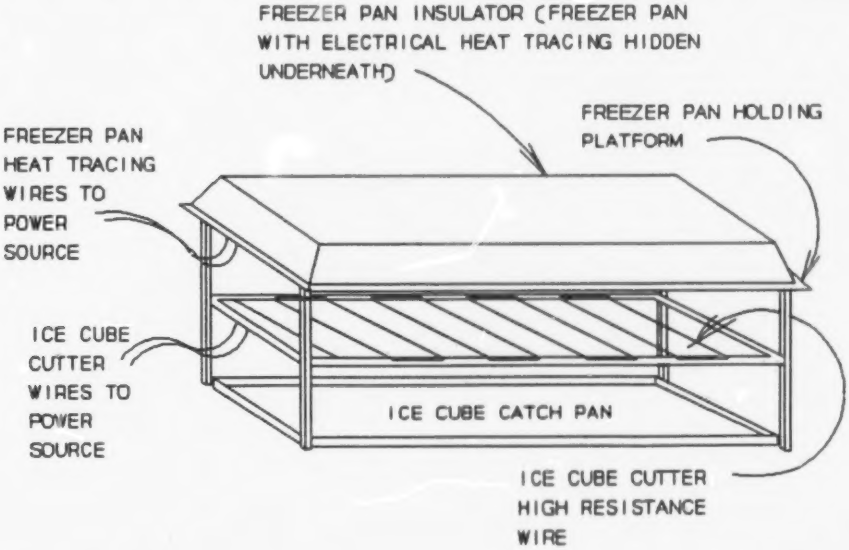

FREEZER PAN INSULATOR (FREEZER PAN WITH ELECTRICAL HEAT TRACING HIDDEN UNDERNEATH)
FREEZER PAN HOLDING PLATFORM
FREEZER PAN HEAT TRACING WIRES TO POWER SOURCE
ICE CUBE CUTTER WIRES TO POWER SOURCE
ICE CUBE CATCH PAN
ICE CUBE CUTTER HIGH RESISTANCE WIRE

Figure C-5-6

Ice Cutting Machine Assembly

2. Have the teacher check the completed control and power circuits before applying voltage.

3. Set the control switch to the "Off" position.

4. Take the mass of an empty freezing pan covered by its insulator using a pan balance and record the measurements in Table C-5-2, "Ice Mass Table."

5. Get a freezing pan full of ice covered by the freezing pan insulator. Immediately measure the total mass of these three items and record measurements in Table C-5-2.

6. Immediately place the full freezing pan of ice inside of its freezing pan insulator, upside-down on the freezing pan holder. Connect the wires of the freezer pan heater to the power circuit voltage as shown in Figure C-5-5. Remember, the freezer pan heater is composed of the wires that are glued to the outside bottom and sides of the freezer pan. Place the experiment insulation shield around the experiment setup.

7. Immediately place the control switch in the freezer pan heater to the "On" position.

8. When the ice block falls out of the freezer pan onto the ice cutting wires, immediately change the control switch from the freezer pan heater "On" position to the ice cube cutter heater "On" position, and start the clock.

9. Record the ice cutter heater current and voltage reading in Table C-5-3, "Ice Cube Cutting Energy Table."

10. Watch the ice block on the ice cube cutter in anticipation of its falling to the tray below as ice cubes. When the ice cubes fall, record the lapsed time on the clock, in seconds, in Table C-5-3.

11. Change the control switch from the ice cube cutter heater "On" position to the "Off" (middle) position.

12. Dry off experimental apparatus. Dismantle the control and power circuits, store parts, and clean up the lab.

Calculations:

Energy required to freeze water (Sensible Heat):

1. Go to Table C-5-2 and complete the indicated subtraction to find the mass of the ice. Record the answer in the proper blank space in Table C-5-2 and again in the proper two spaces in Table C-5-1.

2. Use the formula $\Delta Q = mC\Delta$

ΔQ = sensible heat removed from the water (calories)
m = mass of water (grams)
C = specific heat of water (1 CAL/gm)
ΔT = temperature difference of the water $(T_f = T_i)$ °C

Calculate the sensible heat (ΔQ) removed from the water and record it in Table C-5-1 (column 5, 1st row).

(Latent Head of Fusion):

Use the formula $\Delta Q = mL$

ΔQ = latent heat of fusion removed from the water as it changes state from a liquid to a solid (CAL)
m = mass of water (gm)
L = latent heat of fusion (80 cal/gm)

Calculate the latent heat of fusion removed from the water during its change of state from liquid to solid. Record this calculation in Table C-5-1 (column 5, 2nd row).

Total Heat Loss (Water to Ice)

Place the sum of the heat due to temperature change (ΔQ) and latent heat of fusion in Table C-5-1 (column 5, row 3).

Note: The negative signs for heat due to temperature change and latent heat of fusion mean that energy is taken away from the water.

Energy Required to Cut the Ice

Part 1 (Total Energy)

Use the formula E = P x t = (V x I)t

E = electrical energy
P = power (watts)
V = potential (volts)
I = current (amp)
t = time (sec)

Calculate the electrical energy, in watt*hrs, used by the ice cube cutter heater. Record this in Table C-5-3 (column 4) and Table C-5-4, "Actual Energy Used to Melt Ice for Cutting" (column 1).

Part 2 (Active Wire Length and Applied Energy Ratio)

The active wire length is defined as that length of wire in contact with the ice block. Because the freezer pan width cross section is a trapezoid (see Figure C-5-7, "Trapezoid with Median"), the active wire length is not constant as the ice block is cut. In order to calculate the average wire length for the ice cut, the following formula is used:

WA = 1/2 * (WT + WB)

WA = ave. width (median)
WT = top width
WB = bottom width

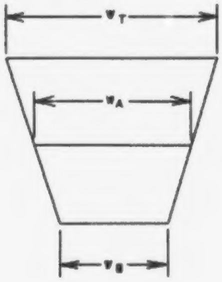


Figure C-5-7

Trapezoid with Median

To calculate the ice block's average width, measure the ice block's top and bottom width from the freezer pan (inside) with a caliper. Also, measure the pan's inside bottom length and record all three results below, completing the indicated calculation for average width (WA). Though the length cross section of the freezer pan is also a trapezoid, the average length or median is not needed since the wires only touch the sides of the ice and not the ends.

1/2 (____________ + ____________) = ____________
top width (cm) bottom width (cm) ave. width (cm)

Length (cm): ______________.

Cut out a piece of paper with a width equal to the above calculated average width and the measured length.

Tape this piece of paper to the heater wires as shown in Figure C-5-8, "Active Wire Tracing," marking the edges wherever a wire passes beyond. Connect the marks in a way that outlines the heater wire in contact with the ice block. (There should be five straight lines like those shown in Figure C-5-8.)

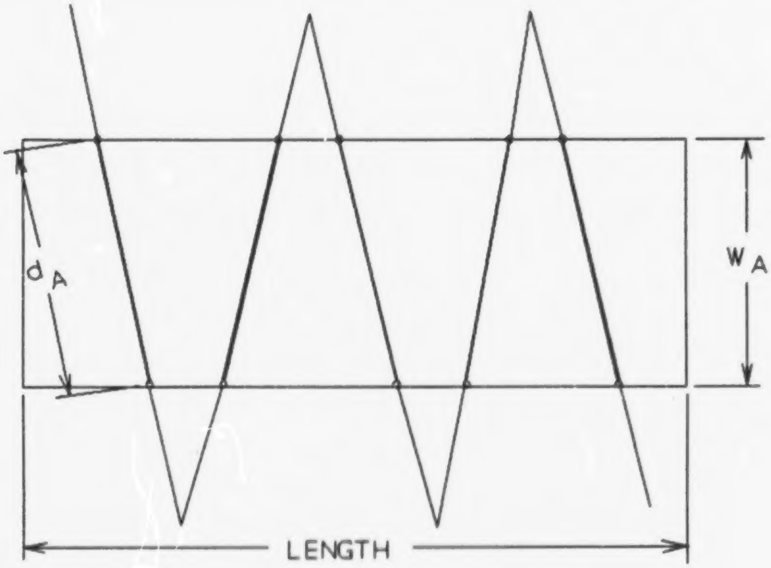


Figure C-5-8

Active Wire Tracing

Using a caliper, measure the diagonal distance of one active wire (d_A in Figure C-5-8) and record below. Since there are five cuts, complete the total active wire length calculation indicated below and record there and in Table C-5-4 (column 2).

______________________ x 5 = ______________________

active wire length (cm) | total active wire length (cm)

You will notice that the Total Active Wire Length calculation placed in Table C-5-4 (column 2) is divided by 43.18, which is the total heater wire length (cm). Therefore, the:

$$\frac{\text{Total Active Wire Length}}{\text{Total Heater Wire Length}} = \text{Applied Energy Ratio}$$

This ratio indicates the approximately percentage (%) of the total heater wire energy actually used to cut the ice, ignoring the energy dissipated to the air. Calculate the actual energy used in Table C-5-4 by multiplying the values in columns 1 through 3, recording the answer in column 4.

Energy Required to Melt Ice for Cutting

Figure C-5-9, "Melted Ice Sections Diagram," shows the five sections of ice that are melted in order to cut through the block. By calculating the volumes of these trapezoid ice sections, the energy required to melt this volume of ice can be calculated using the formula:

$$A = (1/2)\ (h)\ (WT = WB)$$

A = trapezoid area (mm_2)
h = height
WT = top width
WB = bottom width

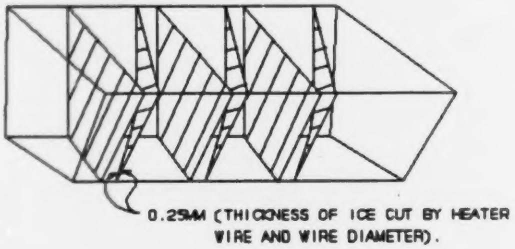

0.25MM (THICKNESS OF ICE CUT BY HEATER WIRE AND WIRE DIAMETER).

Figure C-5-9

Melted Ice Sections Diagram

Record the various measurements in Table C-5-6, "Volume Table," and multiply across as shown.

Note: Notice that column 1 entry is divided by 2.

Convert the column 6 Total Ice Volume in (mm^3) to (cm^3) and record in Table C-5-5, "Energy Required to Melt Ice for Cutting" and multiply across as indicated. Enter the result in column 4 of this table.

The formula for calculating percent error is:

$$\% \text{ Error} = \frac{(\text{Actual Energy} - \text{Calculated Energy})}{\text{Calculated Energy}} \times 100$$

Record your answer here:______________________________%.

Table C-5-1

Ice Freezing Energy Table

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
Type of Heat Energy	Mass of Water (grams)	Specific Heat of Water (cal/g.°C)	ΔT (°C)	Latent Heat of Solidification (cal/gram)	Amount of Energy (calories)
Sensible (Δ_S)		1			
Latent (ΔQ_{LS})				80	
Total (ΔQ_{TF})					

Table C-5-2

Ice Mass Table

Total Mass of Freezing Pan, Insulator and Ice	____________ . gms
Total Mass of Freezing Pan and Insulator (only)	- ____________ . gms
Mass of Ice (subtract line 2 from line 1)	____________ . gms

Table C-5-3

Ice Cube Cutting Energy Table

	Col. 1	Col. 2	Col. 3	Col. 4
Heater Name	Current (amperes)	Potential (volts)	Time On (seconds)	Total Electrical Energy (kilowatt hours)
Ice Cube Cutter				

Table C-5-4

Actual Energy Used to Melt Ice for Cutting

Col. 1	Col. 2	Col. 3	Col. 4
Total Electrical Energy* (kilowatt hours)	Applied Energy Ratio (no. units)	Conversion Factor (Kcal/KWh)	Actual Energy Used (cal)
	÷ 43.18	860	

*From Table C-5-3 - Ice Cube Cutting Energy Table

Table C-5-5

Energy Required to Melt Ice for Cutting

Col. 1	Col. 2	Col. 3	Col. 4
Calculated Total Ice Volume $(cm)^3$	Ice Mass/ Volume $gm/(cm)^3$	Energy to Melt Ice (cal:/gm)	Total Required Energy (cal)
	0.99	80	

Table C-5-6

Volume Table

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
Height (h)	Top width W^T (mm)	Bottom width W^B (mm)	Area (A) (mm^2)	# of Sections (no units)	Total Ice Volume (mm)
÷ 2				5	

ANTICIPATED PROBLEMS:

1. Inaccurate data and conclusions may result from melting ice if the student team is too slow in conducting the experiment.
2. Uneven ice defrosting or cutting may result in part of the ice block falling while the other part is still on the wires.

METHODS OF EVALUATION:

1. Observation of each student team setting up the lab.
2. Grading of laboratory data recording, calculations, and conclusions.
3. Grading the Post-Lab quiz.

FOLLOW-UP ACTIVITIES:

Create your own design for an ice cube machine which is different from the design shown in Figure C-5-3. Be prepared to share your design with the class. Draw as many sketches and diagrams as necessary to illustrate your design.

Brain Teaser: Why is it more efficient to defrost the ice sheet by using hot refrigerant rather than heated electrical wires, when the same amount of energy is required from both sources?

REFERENCES, RESOURCES, RESOURCES:

Harris Ice Delivery
3923 W. 5th Avenue
Chicago, IL 606
Contact: Sylean Harris
(312) 826-3110

POST-LAB QUESTIONS: COLD CUTS: COMMERCIAL ICE CUBE MACHINES

1. The three major processes done by a commercial ice cube machine are:

   a. ____________________

   b. ____________________

   c. ____________________

2. Defrosting the ice block in a commercial ice cube machine may be done in one of the following two ways:

   a. ____________________

   b. ____________________

3. Define the term "heat":

   ____

   ____

4. Define the term "latent heat of fusion":

   ____

   ____

5. Name four applications for the operation principles of the commercial ice cube machine.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

6. Give two reasons for spraying the water to be frozen.

a.____

b.____

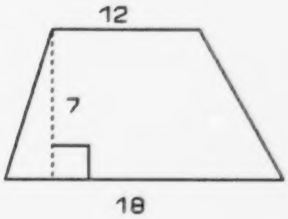
7. Define the term "latent heat of sublimation":

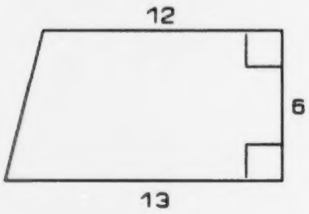
____

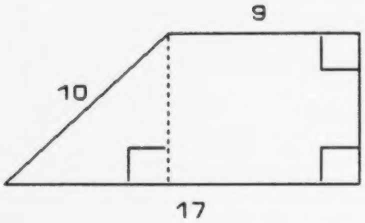
____

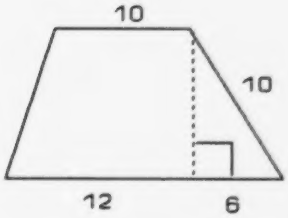
ICE CUTTER MATHEMATICS WORKSHEET

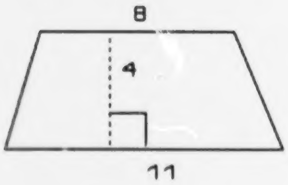
I. Find the area of each trapezoid.

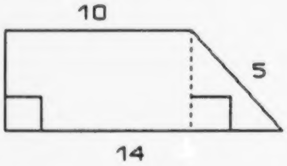












II. Solve the following:

7. $\Delta Q = mL$, for m

8. $D = rt$, for r

9. $I = Prt$, for t

10. $E = VIt$, for I

11. $\Delta Q = mC\Delta T$, for ΔT

12. $\Delta Q = mC\Delta T$, for m.

ACTIVITY 6: AM/FM SIGNALS

TECHNOLOGICAL FRAMEWORK: Students must distinguish between AM and FM signals. Also, students are to find field strength of directionality of antennas, and locate an emitting signal.

PURPOSE:

1. To emphasize the differences between an AM and FM:
   a. frequency
   b. amplitude
   c. photon energy
2. To plot on polar coordinate paper the directionality of field strength of an antenna.
3. To locate a hidden radio transmitter by use of the directionality field strength.

ILLINOIS LEARNER OUTCOMES: As a result of their schooling, students will have a working knowledge of:

- The concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.
- The principles of scientific research and their application in simple research projects.
- The processes, techniques, methods, equipment, and available technology of science.

CONCEPTS:	Physics--frequency, amplitude, wavelength, energy, light speed, electromagnetic wave theory, and field strength. Mathematics--formula substitution, exponential numbers, polar coordinate graphing. Technology Skills--design and construction according to layout, detection of AM/FM signals, oscilloscope, transmitter, and receiver usage.
PREREQUISITES:	Mechanical wave theory, introduction to electromagnetics, oscilloscope usage, some construction of transmitter and receiver.
MATERIALS, EQUIPMENT, APPARATUS:	Oscilloscope, polar graphing paper, transmitter, receiver, calculators, antennas, audio frequency generator.
TIME FRAME:	Four 40-minute classes
TEACHING STRATEGIES:	Students will find unknowns by taking readings and making calculations. Also, students must learn to use antennas to find a hidden transmitter.
TEACHING METHODOLOGY:	Students use oscilloscope to collect various data which will enable them to calculate energy. Also, they will be taught how to use the field strength of an antenna to locate a hidden transmitter.
FURTHER FIELDS OF INVESTIGATION:	Electromagnetic radiation studies, radio control, locating devices such as radar, sonar, etc., radio station operations.

PROCEDURE: Students should build transmitter and receivers before doing this lab activity according to the figures on the following pages.

Prerequisite:

Prior to doing this lab, make sure that students are able to find frequency, amplitude, period, and cycle of waves (an understanding of mechanical waves would be very helpful here). Since we are dealing with EM waves, give them an introduction to the wave and particle theory, as well as a short explanation (if possible) of Einstein's theory concerning the energy of a photon. Technology instructors should help students construct transmitters (one AM and one FM), receivers, and teach students how to use and read the oscilloscope (if they haven't done so before). Also, go through the usage of the Audio Frequency Generator with them. Mathematics teachers should work with the students on rearranging of formulas to isolate and solve for an unknown, as well as usage of exponentials (10-3, 106, etc.). Teach triangulation at this point (needed in Part 2).

This lab is divided into two parts. The first concerns finding the differences between an AM and FM signal. The second will emphasize the directionality and strength of the signal which consequently will enable the student to pinpoint the location of the sending source.

In Part 1, the students will be using the AM and FM transmitters that they have put together along with the oscilloscope. They will read the amplitude and period of the wave generated onto the oscilloscope (three different signals each for AM and FM randomly selected by the teacher or student). The signals will be altered (modulated to give different tones) by using the Audio Frequency Generator. From this point, the student will make calculations to find frequency, wavelength, energy, and mass of a photon.

Main Points for Students to Understand:

1. Identify differences between AM and FM.
2. Understand how frequency and wavelength affect the energy of mass of a photon.
3. The numbers of the radio dial are actually the frequencies of transmission and not numbers just for their convenience in locating a station.

In Part 2, the students will be constructing a wooden chassis to hold the receiver and the antenna which they will make. With the transmitter (AM and FM) sending, and the oscilloscope connected to the receiver, the students will take readings from the oscilloscope and plot them onto polar coordinate graphing paper. Each reading will correspond to a horizontally rotated angle. Consequently, they will get a graph which shows a directionality strength pattern of that antenna. Then the students will pinpoint the location of a transmitter (placed secretly by the instructor in an undisclosed area), with the information gained about that antenna. This activity is like an army game where the teams must locate an enemy transmitting station. (The instructor may have an AM transmitter and an FM transmitter going at the same time, and there would be an AM and FM team both working during the same time--this way all the students will be busy and can see that this can be done for AM as well as FM. The instructor can even make this assignment into a contest.) Triangulation will be used.

Main Points for Students to Understand:

1. Antennas have a directional pattern.

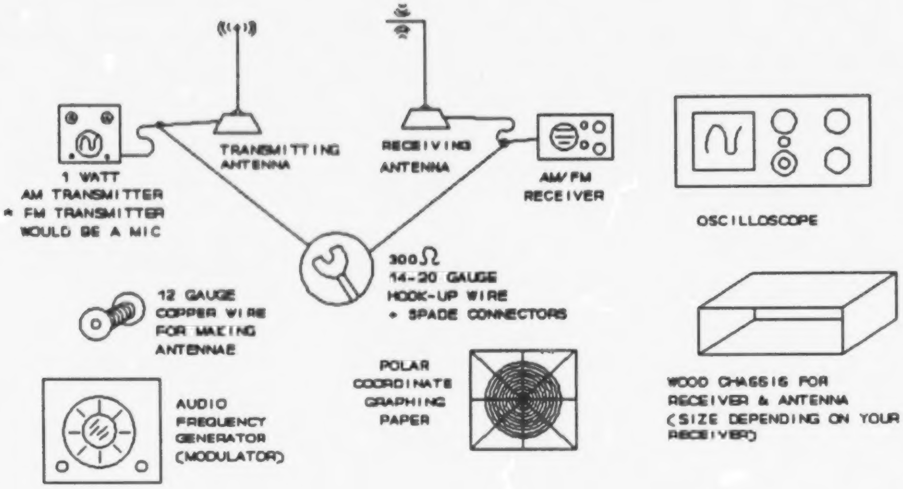
2. Usage of the directional pattern of antennas can improve receiving of transmission signals.

3. Consequently, the location of the transmission can be determined.

Connecting a radio or having a student speak into a microphone that transmits to the oscilloscope to show what kind of waves they generate would be a good idea before or after the lab is done. The students can take notes on the visual differences between AM and FM. (The instructor can decide if he/she wants to do this.)

PART 1

Materials:


1 WATT
AM TRANSMITTER
* FM TRANSMITTER
WOULD BE A MIC
TRANSMITTING
ANTENNA
RECEIVING
ANTENNA
AM/FM
RECEIVER
OSCILLOSCOPE
300Ω
14-20 GAUGE
HOOK-UP WIRE
+ SPADE CONNECTORS
12 GAUGE
COPPER WIRE
FOR MAKING
ANTENNAE
POLAR
COORDINATE
GRAPHING
PAPER
WOOD CHASSIS FOR
RECEIVER & ANTENNA
(SIZE DEPENDING ON YOUR
RECEIVER)
AUDIO
FREQUENCY
GENERATOR
(MODULATOR)

Step 1: Hook up the AM transmitter to the audio frequency generator and then to the oscilloscope (see Figure C-6-1, "Hook-up"). We will do three trials of different signals (tones) through usage of the modulator.

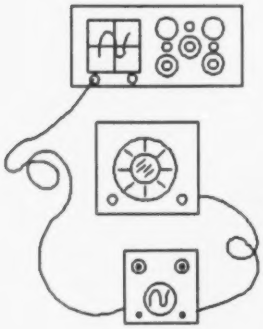


Figure C-6-1

Hook-up

Step 2: Start transmitter and adjust your oscilloscope Time/Div setting until a stable wave reading is achieved. (Again, if you need assistance, see your instructor.)

You should be reading the period of the wave at this point as well as the amplitude. (Remember, the reading is per division.)

Period: Read ↔ Amplitude: Read ↕

Randomly select three different settings on your signal modulator.

Step 3: Record your readings for the AM signals in each box.

	Trial 1		Trial 2		Trial 3
Period	mS		mS		mS
		AM		AM	
Amplitude	V		V		V

Step 4: Repeat Steps 1-3, substituting the AM transmitter with the FM transmitter. Then record the data below (three trials).

	Trial 1		Trial 2		Trial 3
Period	mS		mS		mS
		FM		FM	
Amplitude	V		V		V

Step 5: Since we know that the frequency of a wave is equal to 1/period, record the frequency for each trial (AM and FM).

	Trial 1	Trial 2	Trial 3
Frequency AM (f)	Hz	Hz	Hz
Frequency FM (f)	Hz	Hz	Hz

Speed of all EM waves = m/S

This value is called "C".

Step 6: Before we find the energy difference between an AM and FM signal, let's find the wavelength for each of the frequencies above:

(use $\lambda = \frac{c}{f}$)

	Trial 1	Trial 2	Trial 3
AM Wavelength (λ)	m	m	m

Show work here:

	Trial 1	Trial 2	Trial 3
FM Wavelength (λ)	m	m	m

Show work here:

Step 7: To find the energy (photon) of the signal, we need the equation E = hf. h is Plank's Constant which is 6.6 x 10^{-34} j.sec.

	Trial 1	Trial 2	Trial 3
AM Energy (E)	j	j	j

Show work here:

	Trial 1	Trial 2	Trial 3
FM Wavelength (E)	j	j	j

Show work here:

PART 1: POST-LAB QUESTIONS

1. Did the frequency change for the AM signals?____________________

2. Did the frequency change for the FM signals?____________________

3. Did the amplitude change for the AM signals?____________________

4. Did the amplitude change for the FM signals?____________________

5. List the basic differences between an AM and an FM signal.

____

____

____

6. AM is an abbreviation. Based on what you observed on the oscilloscope, what do you think AM stands for?__________________

____

7. How about FM?____

____

8. How did the calculated Energy values of the AM signals compare to the Energy values of the FM signals?

____

____

9. What effects does a Long Wavelength have on Energy?______________

____

10. What about a Short Wavelength?__________________________________

____

11. What effect does High Frequency have on Energy?_________________

____

12. How about Low Frequency?_______________________________________

AM-FM COMPUTER ACTIVITY

Use graphing software such as Omnifarious Plotter (public domain).

Have students study the effects of varying A and B in the equation:

$$y = A \sin Bx$$

Students should be able to conjecture that A affects the height the height of the curve--which you can then tell them is amplitude, and B affects the number of cycles completed in Pi radians or 360 degrees--which you can then tell them is the period or the frequency.

Communication, both written and oral, is important in Mathematics. You may have to guide students through the Observation section. Don't discuss amplitude and frequency prior to this worksheet. Let the students develop some terms of their own to describe the effects of A and B on the curve.

Graph each pair of equations on the same set of axes. Sketch the graphs on this worksheet.

1. $y = \sin(x)$

   $y = \sin(2x)$

2. $y = \sin(x)$

   $y = \sin(.5x)$

3. $y = \sin(x)$

   $y = 2\sin(x)$

4. $y = \sin(x)$

   $y = .5\sin(x)$

5. $y = \sin(x)$

Observations:

PART 2 - ELECTROMAGNETIC WAVES

Electromagnetic and mechanical waves have some things in common. They both have frequency and amplitude. But there is one important difference between them--the need for a transmission medium! The classic Physics experiment, where an electric bell is placed inside of a bell jar and a vacuum is formed, illustrates this difference. Before the vacuum is formed, the ringing bell can be both seen and heard. After the vacuum is formed, however, there is no sound though the moving clapper can be seen. Thus, the sound wave is medium-dependent, while the light, an electromagnetic wave, is not. The medium in this case is air.

Since modern electronics allows the detection of radiated electronic waves, at great distances from their origin, they are useful in communications. Let us take a look at how electromagnetic waves are radiated.

As you know, a current-carrying conductor has a magnetic field surrounding it. The size of this magnetic field is directly proportional to the number of electrons flowing through the wire. In addition, the direction of this magnetic field is dependent on the direction of current flow. The Left Hand Rule is used to determine the direction of the magnetic field when the current flow direction is known. The electron flow in the conductor is due to a potential difference, which produces an electric field. The electrons flow parallel to this electric field, from a negative potential to a positive potential. Therefore, the Left Hand Rule shows us that the induced magnetic field is perpendicular to the electric field causing the electron flow. If a periodically changing electric field is used, then a periodically changing magnetic field is also produced. If the frequency of these periodically changing fields is high enough, expanding fields are produced before the collapsing fields are zero. Since lines of force, whether electric or magnetic, cannot cross and the new expanding electric and magnetic fields are stronger than the collapsing fields, the collapsing fields' electric and magnetic energy is accelerated away. This bundle of electric and magnetic energy is the electromagnetic wave which allows us to communicate at small and great distances. Note that the amount of energy in the radiated wave increases as the frequency increases, which also means that shorter waves, since they have a higher frequency, have more radiated energy than longer waves.

Remember that the limitations on the use of amplitude modulation and frequency modulation to certain frequencies are governmental and not physical.

The primary device used to produce and receive electromagnetic radiation is the antenna. The radiation pattern of an antenna shows the antenna's energy output or reception in pictorial form. Look at Figure C-6-2, "Omnidirectional Antenna Pattern," and Figure C-6-3, "Beam Antenna Pattern," as examples.

Figure C-6-2 shows an energy pattern which is a circle. Since the antenna is understood to be at the center of the diagram, this means that the energy output or reception is equal for the whole 360 degrees around it. The opposite of Figure C-6-2 is Figure C-6-3, which shows a narrow lobe or beam for an energy pattern. This means that all of the antennas's energy is within this lobe, with the highest energy being on the lowest radius from the center of the diagram.

Let us compare these two antennas in the transmitting mode. The omnidirectional antenna puts out an even signal in all directions, which means that rotating it about its axis has no effect on its radiation pattern. The beam antenna, on the other hand, has such a narrow or concentrated pattern, that rotation about its axis causes great change. Therefore, the omnidirectional antenna broadcasts to receivers in all directions around it, while the beam antenna must point its lobe or beam in the direction of a receiver in order to transmit a signal.

Now, let us compare both antennas in the receiving mode. The omnidirectional antenna receives signals from all directions, while the beam antenna must be aimed in the direction of a transmitter in order to pick up the signal.

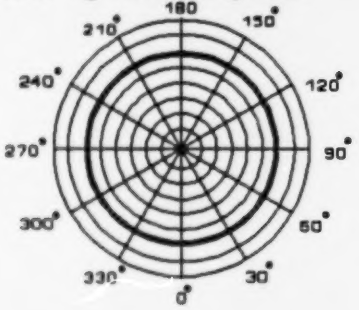


Figure C-6-2

Omnidirectional Antenna Pattern

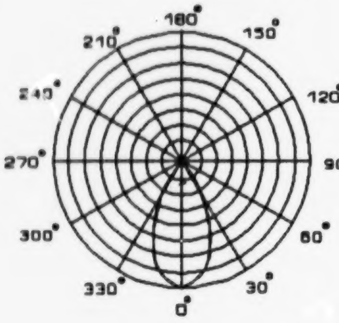


Figure C-6-3

Beam Antenna Pattern

Therefore, the beam antenna is said to be directional, while the omnidirectional antenna is said to be non-directional. There is a measurement for an antenna's directionality and it is called "beam width." The beam width is calculated by finding two points on a radiation pattern where the value is 70.7% of the maximum value, drawing lines from these two points to the center of the diagram, then measuring the angle between the two lines. Figure C-6-4, "Antenna Beam Width Illustration," shows how beam width is calculated.

You will notice that the maximum field strength for the antenna in Figure C-6-4 is seven units. That is, the signal strength reaches, but does not extend beyond, the seventh or outermost concentric circle. Therefore, in order to find the 70.7% field strength points on the diagram, the following multiplication is done: 7 x 0.707 = 4.95 units. Finding the two points where the pattern crosses the 4.95 unit points, two dots are made (see Figure C-6-4). Two straight lines are drawn from these dots to the center of the graph and extended beyond the graph itself. The beam width is between 330 and 30 degrees; thus it equals 60 degrees.

This experiment uses relative field strength, which has no dimensions, to plot antenna radiation patterns. The same patterns are produced with the use of field strength meters, which cost about $10,000 new. However, relative field strength readings do not allow many of the calculations that actual field strength readings permit. Actual field strength measurements result in readings of microvolts per meter.

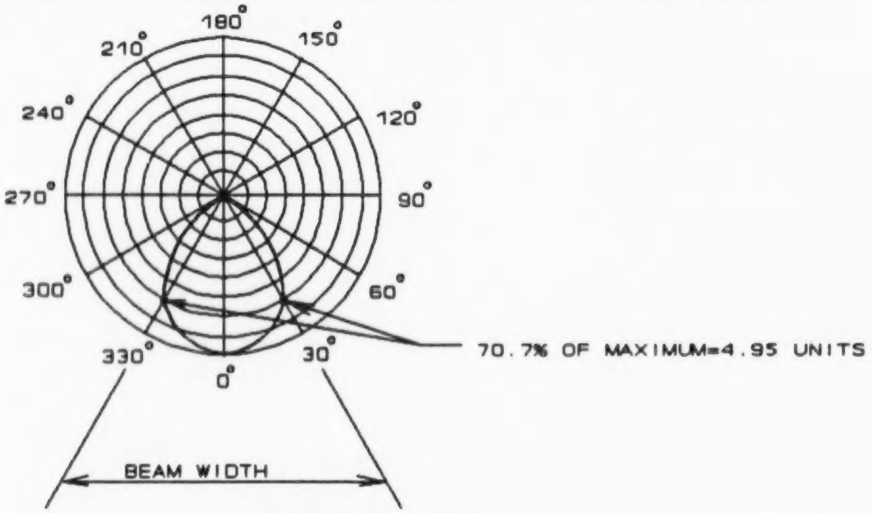


Figure C-6-4

Antenna Beam Width Illustration

AM/FM SIGNALS - PART 2

Purpose

The purpose of Part 2 of this experiment is to (1) show how basic radio frequency antennas work, and (2) show how antenna radiation patterns are plotted and their meaning.

Summary of Procedure

The second part of this laboratory experiment will test two types of basic antennas for their radiation patterns. One antenna will use an amplitude modulated (AM) signal and the other a frequency modulated (FM) signal. After plotting the two antenna radiation patterns, several teams will join together in locating a hidden transmitter using the triangulation method.

Procedure

1. Connect the audio frequency (AF) generator, amplitude modulated (AM) transmitter, and the vertical quarter wave (Marconi) transmitting antenna as shown in Figure C-6-5, "A.M. Transmitter Hookup." Also see Figure C-6-6, "Plug for Electrical System Ground." Note that when this plug is inserted into a standard power receptacle, the electrical system ground is utilized.
2. Connect the vertical quarter wave receiving antenna, amplitude modulated receiver, and the oscilloscope as shown in Figure C-6-7, "AM Receiver Hookup."
3. Turn power "On" to the transmitter and receiver and tune the receiver to the transmitter signal. The receiver volume control must remain fixed throughout the experiment.
4. Rotate the receiving antenna 360 degrees about its axis and adjust the oscilloscope vertical amplification in a way that the largest signal will be on the screen and the smallest signal will be at least one unit.
5. Rotate the receiving antenna about its axis in 30-degree intervals, through 360 degrees, recording the oscilloscope amplitude reading at each interval and recording it in Table C-6-1, "AM Antenna Radiation Pattern."

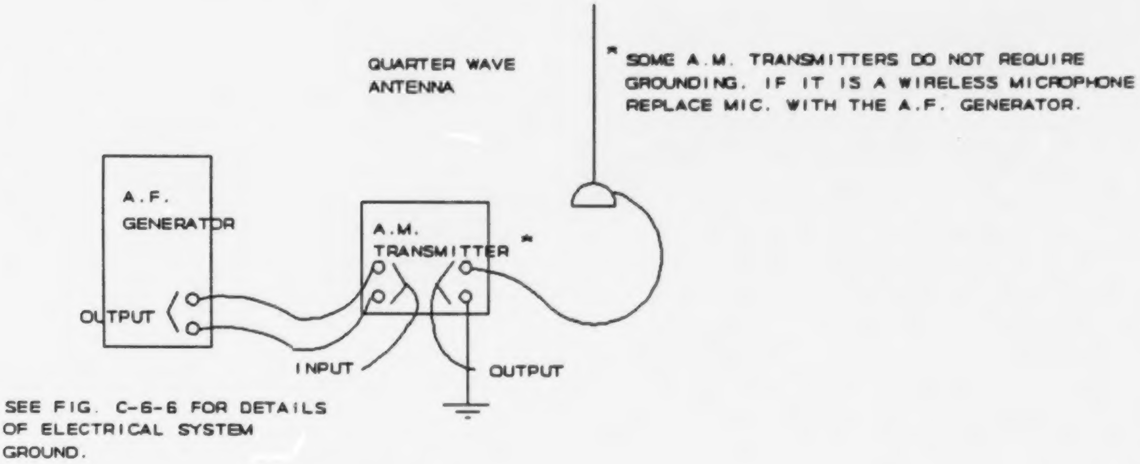

QUARTER WAVE ANTENNA
* SOME A.M. TRANSMITTERS DO NOT REQUIRE GROUNDING. IF IT IS A WIRELESS MICROPHONE REPLACE MIC. WITH THE A.F. GENERATOR.
A.F. GENERATOR
A.M. TRANSMITTER *
OUTPUT
INPUT
OUTPUT
SEE FIG. C-6-6 FOR DETAILS OF ELECTRICAL SYSTEM GROUND.

Figure C-6-5

AM Transmitter Hookup

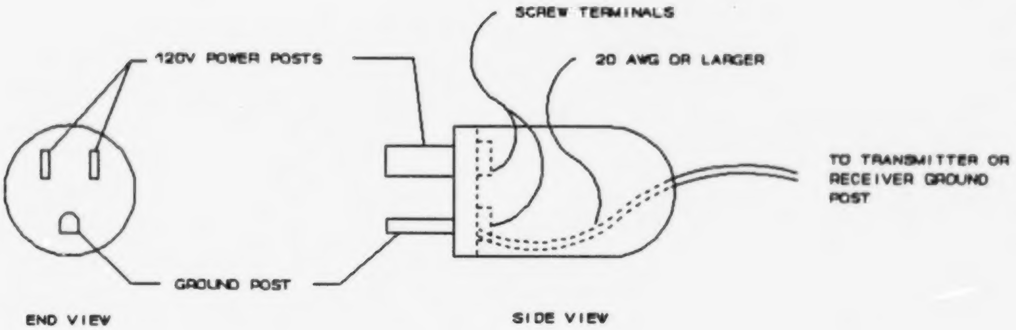

SCREW TERMINALS
120V POWER POSTS
20 AWG OR LARGER
TO TRANSMITTER OR RECEIVER GROUND POST
GROUND POST
END VIEW
SIDE VIEW

Figure C-6-6

Plug for Electrical System Ground

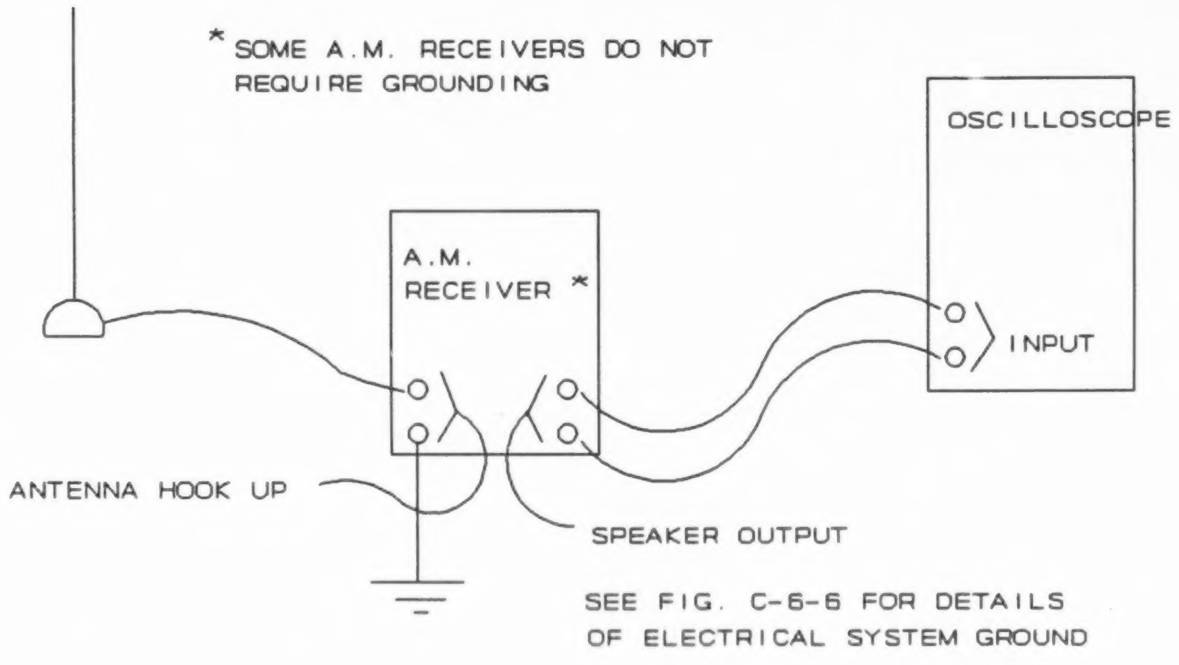

* SOME A.M. RECEIVERS DO NOT REQUIRE GROUNDING
OSCILLOSCOPE
A.M. RECEIVER *
INPUT
ANTENNA HOOK UP
SPEAKER OUTPUT
SEE FIG. C-6-6 FOR DETAILS OF ELECTRICAL SYSTEM GROUND

Figure C-6-7

AM Receiver Hookup

6. Connect the audio frequency (AF) generator, frequency modulated (FM) transmitter, and the horizontal half-wave (Hertz) transmitting antenna as shown in Figure C-6-8, "FM Transmitter Hookup."

7. Connect the horizontal half-wave receiving antenna, frequency modulated receiver, and the oscilloscope as shown in Figure C-6-9, "FM Receiver Hookup." Align the receiving antenna ends parallel to the 270 and 90 degree lines of the transmitting antenna axis.

8. Turn power "On" to the transmitter and receiver and tune the receiver to the transmitter signal. The receiver volume control must remain fixed throughout the experiment.

9. Rotate the receiving antenna 360 degrees about its axis and adjust the oscilloscope vertical amplification in a way that the largest signal will be on the screen and the smallest signal will be at least one unit.

10. Rotate the receiving antenna about its axis in 30 degree intervals, through 360 degrees, recording the oscilloscope amplitude reading at each interval and recording it in Table C-6-2, "FM Antenna Radiation Pattern."

11. Ask the instructor which receiver and antenna system should be connected to the oscilloscope for the hidden transmitter hunt. Get a scale copy of the room layout and hook up the system components.

12. Meet with the other laboratory teams looking for the same hidden transmitter and decide how the teams will be positioned for the hunt.

13. Rotate the receiving antenna until the strongest signal is received. Draw a line perpendicular from the middle of the broad side of the receiving antenna, plotting this line on the room layout you got from the instructor.

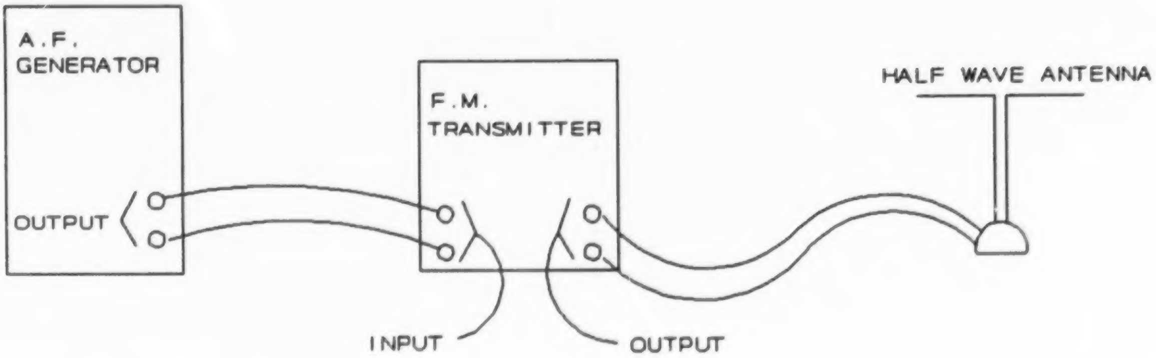

A.F.
GENERATOR
OUTPUT
F.M.
TRANSMITTER
HALF WAVE ANTENNA
INPUT
OUTPUT

Figure C-6-8

FM Transmitter Hookup

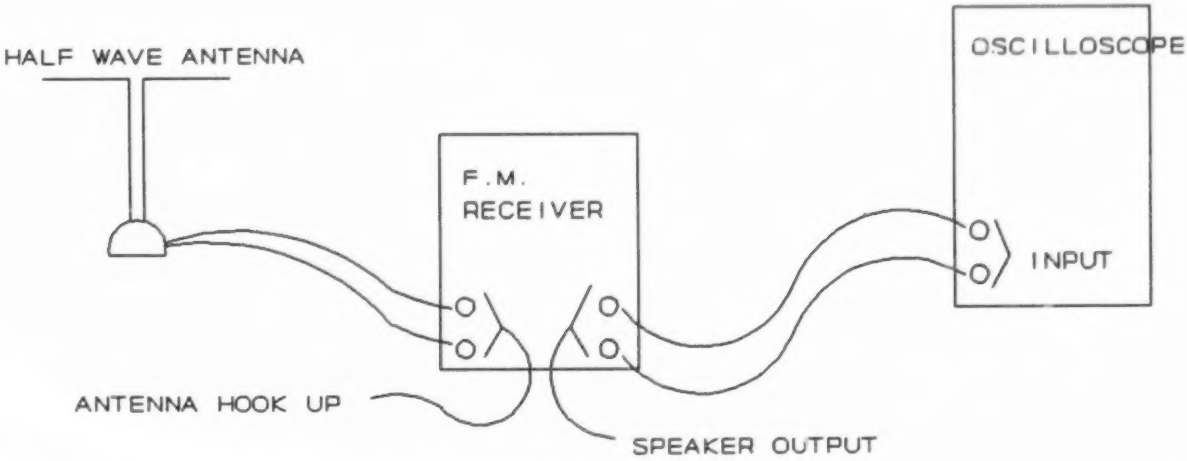

HALF WAVE ANTENNA
OSCILLOSCOPE
F.M.
RECEIVER
INPUT
ANTENNA HOOK UP
SPEAKER OUTPUT

Figure C-6-9

FM Receiver Hookup

Table C-6-1

AM Antenna Radiation Pattern

Position (degrees)	Amplitude (relative)
0	
30	
60	
90	
120	
150	
180	
210	
240	
270	
300	
330	
360	

Table C-6-2

FM Antenna Radiation Pattern

Position (degrees)	Amplitude (relative)
0	
30	
60	
90	
120	
150	
180	
210	
240	
270	
300	
330	
360	

CALCULATIONS

1. **Antenna Radiation Patterns**

The data from Tables C-6-1 and C-6-2 are to be plotted on polar coordinate graph paper to obtain the antenna radiation patterns. Plotting polar coordinates has been covered in Mathematics class.

2. **Beam Width**

a. A.M. (quarter wave antenna):

____________________ x 0.707 = ____________________
100% signal (units) beam width points (units)

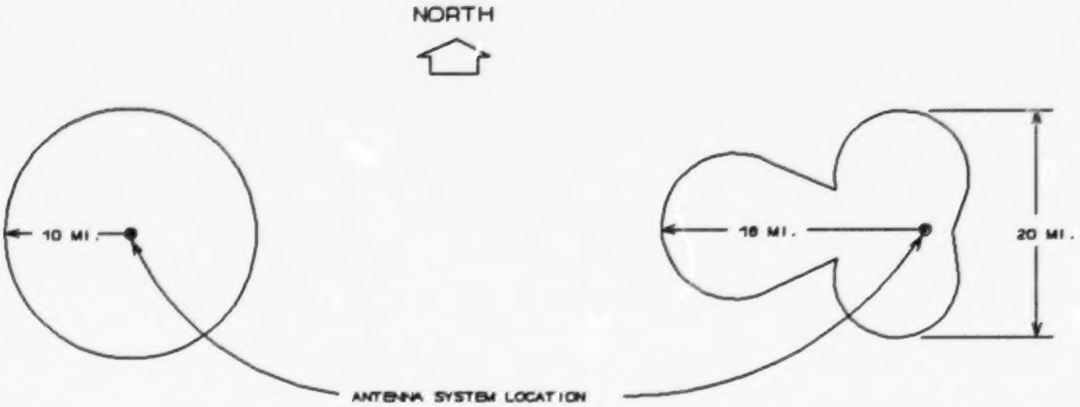
____
beam width (degrees)

b. F.M. (half wave) antenna:

____________________ x 0.707 = ____________________
100% signal (units) beam width points (units)

PART 2: POST-LAB QUESTIONS

1. Were the radiation patterns from this experiment symmetrical? If they were, why? If they were not, why?



Pattern 1

Pattern 2

Figure C-6-10

Antenna System Location

Which one of the two antenna radiation patterns above (see Figure C-6-10, "Antenna System Location") would you prefer for your Chicago radio station with transmitters in the downtown area (midway between the north and south boundaries, near Lake Michigan)? Explain the reason(s) for your choice. Assume that the area coverage for each pattern is equal and that the cost of both antenna systems is close. You may want to look at a map of the Chicago area before making a decision.

3. Two locations, 100 miles apart, must have two-way communications. There is an omnidirectional and narrow beam antenna system available. Which antenna system can offer a savings in radio equipment by reducing the power requirements? Explain how one antenna system can offer a reduced power requirement over the other.

INSTRUCTOR NOTES

Depending on the equipment in one's electronics laboratory/shop, this part of the experiment can be done in several ways. In an effort to clarify the choices, the alternatives have been put into Table C-6-3, "Component Choices." You may pick any combination of alternatives which allow you to do the laboratory experiment. For example, a combination of alternatives 1, 2, and 5, combined with standard laboratory equipment and simple antennas, are enough to complete Part 2 of this experiment.

Table C-6-3

Component Choices

Component Description	Category				Information Sources/ Comments
	Trans.		Recv.		
	AM	FM	AM	FM	
1. AM Wireless Microphone	x				Schematic [1]
2. FM Wireless Microphone		x			Kit [2], Training Module [3], Retail
3. AM (Broadcast Band)			x		Kit [2], Training Module [3], Retail
4. FM (Broadcast Band)				x	Training Module [3], Retail
5. AM/FM (Broadcast Band) Radio			x	x	Kit [4], Retail
6. Model Radio Control Transmitter	x				Kit [4], Retail
7. Model Radio Control Receiver			x		Kit [4], Retail
8. Low Frequency Transmitter	x				Schematic [5]
9. Low Frequency Converter			x		Schematic [6], AM Radio Required

INFORMATION SOURCES/COMMENTS CODE KEY FOR TABLE 3*

[1] Master Handbook of 1001 Practical Electronic Circuits. Schematic copy included with this laboratory equipment. Encyclopedias of electronic circuits have similar schematics.

[2] Heath Company. Other kit companies have similar products.

[3] Lab-Volt Division of Buck Engineering Co., Inc. Other manufacturers have similar products.

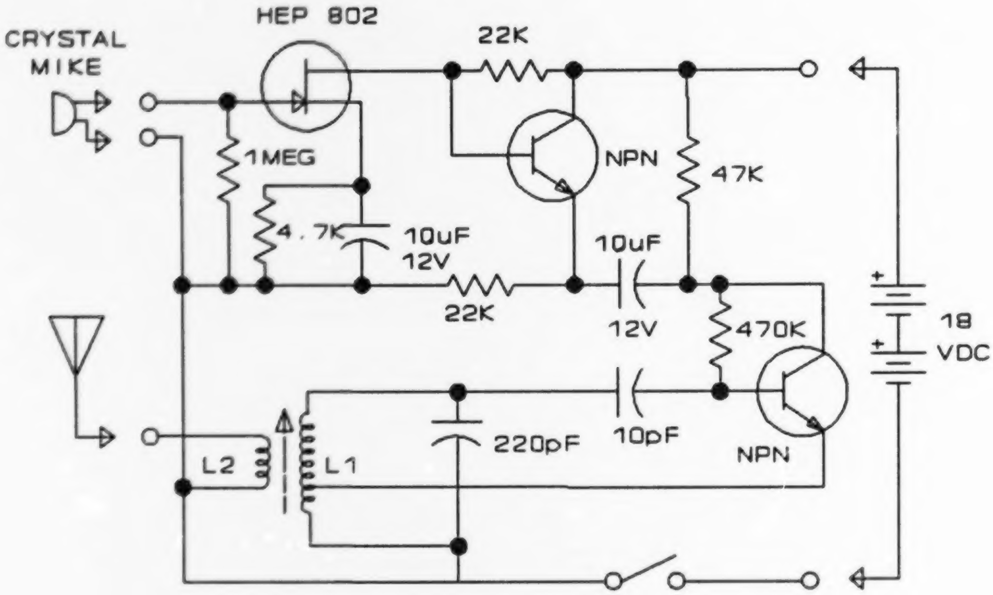
[4] Marcraft International Corp. Other manufacturers have similar products.

[5] Radio Electronics Magazine, September 1989, pp. 43-46, 63.

[6] Ibid., pp. 47-50.

*For addresses, see "References, Resources, Vendors" section.

You might also utilized an AM wireless transmitter as shown in Figure C-6-11, "AM Wireless Transmitter."


HEP 802
CRYSTAL MIKE
22K
1MEG
4.7K
10uF 12V
NPN
47K
10uF
22K
12V
470K
18 VDC
220pF
10pF
NPN
L2
L1

L1 - FERRITE ANTENNA COIL (VARIABLE)
L2 - (See Text)

A.M. WIRELESS TRANSMITTER: USEFUL FOR BABY-SITTING, SICK WATCH, INTERCOM ,ETC. LI IS A VARIABLE ANTENNA COIL (CALECTRO D1 841). L2 IS FOUR TURNS OF HOOKUP WIRE WOUND ON TOP OF L1. Q2-3 ARE NPN SILICON TRANSISTORS (CALECTRO K4-507).

Figure C-6-11

AM Wireless Transmitter

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POLAR COORDINATES MATHEMATICS WORKSHEET

Antenna radiation patterns are drawn on polar coordinates graph paper, which requires knowledge of Polar, the Coordinate System. The Polar Coordinate System is also the basis for aircraft and ship navigation on the earth. Before going into this "new" coordinate system, a brief review of a "known" system, the Rectangular Coordinate System, will be conducted (see Figure C-6-12, "Rectangular Coordinate System").

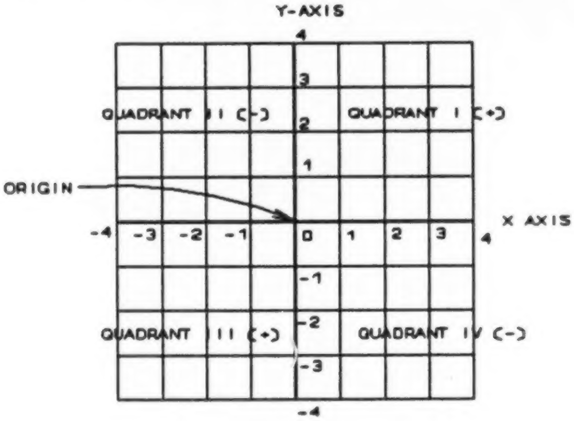

Figure C-6-12

Rectangular Coordinate System

Figure C-6-12 shows a basic rectangular coordinate system. The horizontal axis is called the x-axis. The vertical axis is called the y-axis and the point where the two axes cross is the origin. The x-coordinate or abscissa is the number which gives a point's location along the x-axis, while the y-coordinate or ordinate is the number which gives a point's location along the y-axis. Thus, this two-dimensional system needs two numbers to locate any point in its plane. These two numbers are called coordinates. To reduce confusion about which number represents the x or y axis, the x-coordinate is given first and the y-coordinate is given second. This special way of expressing a point's coordinates is called an "ordered pair" and has the written form: (x,y). Therefore, the illustrated point in Figure C-6-12 has the ordered pair (2,3). You will notice that sections of the x and y axes have different signs. The x-axis is positive to the right of the origin or center, and negative to the left side. The y-axis is positive above the origin and negative below it. The crossing axes form four areas called quadrants which are shown in Figure C-6-12. The signs for these quadrants come from the multiplication of bordering x and y axis signs. Thus, quadrant IV has a negative sign because the positive x-axis is multiplied by a negative y-axis. This completes the review of the Rectangular Coordinate System; thus, we move on to the "New" Polar Coordinate System.

Figure C-6-13 shows a simplified Polar Coordinate System. It is easy to see that this system also has x and y axes that cross in the center, like the Rectangular Coordinate System. The center point, however, is named differently and is called the "pole." Units on the axes are formed by concentric circles (circles within larger circles) with the pole as their common center. Like the rectangular coordinate system, the polar system is two dimensional and has two coordinates in an ordered pair. However, these two coordinates are different. The first coordinate represents the distance traced from the pole or center to the point in question. This distance is called the "magnitude" and is denoted by the symbol ρ, the Greek letter rho. The second coordinate presents the angle traced from the right end of the x-axis (shown as 0 or 360 degrees), going counterclockwise to the point in question. The symbol for this angle is θ, the Greek letter theta, and is called the "argument." The ordered pair for polar coordinates is written ρ/θ, and is read "rho angle theta." Therefore, the illustrated point in Figure C-6-13 has the ordered pair (3/60). On television, the radar operator is using this system when he gives the range (ρ) in yards and bearing (θ) in degrees of an object.

Figure C-6-14 is a Polar Coordinate System which has negative degrees as well as positive degrees. This more complicated figure is a real one! Figure C-6-13 was used first to make the tracing of your first polar coordinate point more simple. Now that you know how to trace polar coordinates, two complicating concepts can be introduced. The first concept is that of tracing the angle θ, going in a counterclockwise direction from 0 or 360 degrees. Going in this direction, our example traces out minus 300 degrees. The point did not change position. It just shares that position with both angles, 60 and -300 degrees.

The second concept is that of multiple rotations. Going back to the example, if counterclockwise tracing from point 3/60, was continued one more full circle (360 degrees), the same position becomes 60 plus 360 degrees, or 420 degrees! If this same point was traced out, going in the clockwise direction, the position becomes -300 plus -360 degrees, or -660 degrees. The point is that unlike the Rectangular Coordinate System, where one point has only one set of coordinates, a point in the Polar Coordinate System can have an infinite number of coordinates. This infinite set of coordinates must be whole-number multiples of angle θ. Please don't panic over this second concept--it will not matter in this experiment!

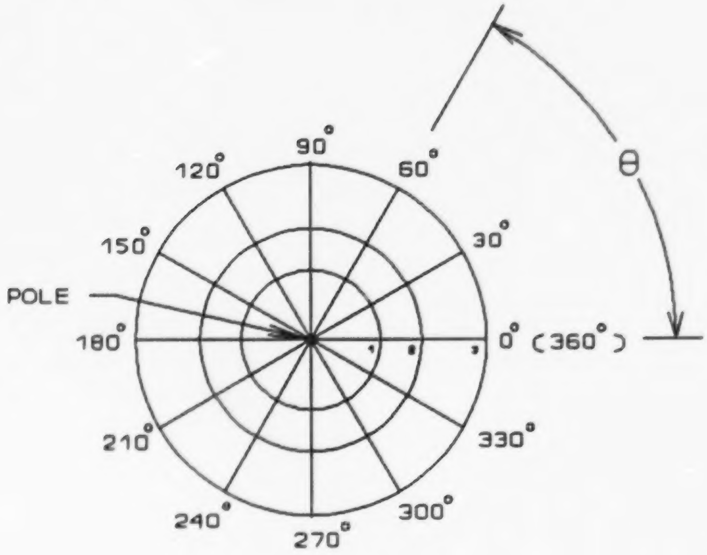
90°
120°
60°
θ
150°
30°
POLE
180°
0° (360°)
1
2
3
210°
330°
240°
300°
270°

Figure C-6-13

Simplified Polar Coordinate System

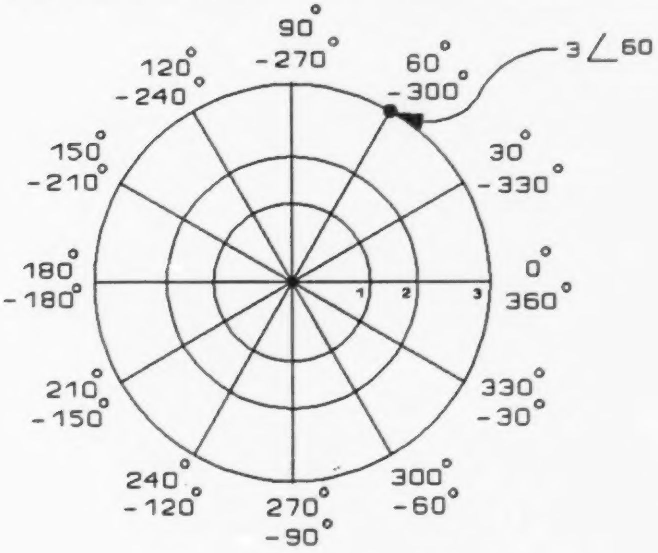
90°
-270°
120°
-240°
60°
-300°
3∠60
150°
-210°
30°
-330°
180°
-180°
0°
360°
1
2
3
210°
-150°
330°
-30°
240°
-120°
270°
-90°
300°
-60°

Figure C-6-14

Polar Coordinate System

ANTICIPATED PROBLEMS: Interference from other sources and rebounding off walls; readings may not be 100% accurate off of oscilloscope; may take time for student to do graphing.

METHODS OF EVALUATION: Location of hidden transmitter; completion of graph, quiz, and questioning.

FOLLOW-UP ACTIVITIES: Visit Broadcasting Museum, build radio-controlled vehicles (cars, boats, airplanes) for race, visit Great Lakes Naval Base to see how they locate signals, incoming planes, etc.

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Frenzel, L. (1989). Communication electronics. New York: McGraw-Hill, pp. 191-211.

Harter, J., & Beitzel, W. (1984). Mathematics applied to electronics (2nd ed.). Reston, VA: Reston Publishing, pp. 236-239, 424-426.

Nelson, R. A. (1989, September). Low Frequency Transmitter. Radio Electronics Magazine. pp. 43-46, 63.

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Themes, L. (1974). Communication electronics for technicians. New York: McGraw-Hill, pp. 271-298.

Sheets, W., & R. F. Graf. (1989, September). Low Frequency Converter. Radio Electronics Magazine, pp. 47-509.

RESOURCES:

Gomall, P., Engineer, Federal Communications Commission, Field Operations Bureau, 1550 Northwest Highway, Park Ridge, IL 60068, telephone (312) 353-0195.

Spiwak, M. (ed.). Radio electronics magazine. Gernback Publishing, 500-B, BI-County Blvd., Farmingdale, NY 11735, telephone (516) 293-3000, X-225.

VENDORS:

Heath Company
P.O. Box 8589
Benton Harbor, MI 49022-8589
1-800-253-0570

Lab-Volt Division of Buck Engineering Co., Inc.
P.O. Box 686
Farmingdale, NJ 07727

Marcraft International Corporation
100 W. Morain St.
Kennewick, WA 99336
1-800-441-6006